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Aircraft-Engine Research of the National Advisory Committee for Aeronautics

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ABSTRACT

Some of the outstanding results recently obtained by the National Advisory Committee for Aeronautics in the research on aircraft power plants are presented. The subject of fuel injection with both gasoline and the new safety fuels is discussed. The problem of improving the cooling of air-cooled cylinders by increasing the fin surface has been investigated. A cylinder has been constructed and tested having preformed sheet-metal fins bonded to the cast aluminum-alloy cylinder head. The results of performance test on a 2-stroke-cycle liquid-cooled and a 4-stroke-cycle air-cooled Diesel engine are discussed.

INTRODUCTION

NEVER before in the history of aeronautics has there been such a demand for high speed in military airplanes. To obtain the desired high speeds requires the development of engines of approximately 2000 horsepower having small frontal areas. This demand has caused a swing from air-cooled back to liquid-cooled engines, at least, for high-speed military airplanes.

The air-cooled engine has not reached, by any means, its maximum power output. The several researches of the Committee, particularly on cylinder cooling, have shown possibilities of large increases in power output from air-cooled cylinders.

It is the purpose of this paper to point out some of the results obtained from recent investigations of the Committee that indicate possibilities for further increasing the safety and power output and reducing the fuel consumption of aircraft engines.

Presented at the West Coast Annual Meeting, I.Ae.S., Pasadena, California, June 17, 1939.

FUEL INJECTION

The desired degree of atomization required of liquid fuels suitable for present aircraft engines may be obtained by the use of a carburetor, a fuel-injection system injecting into the manifold, or a system injecting into the engine cylinder. The principal advantages claimed for the use of fuel-injection systems, as compared with the use of a carburetor, are freedom from icing, improved fuel distribution and acceleration, and scavenging of the combustion chamber without the loss of fuel by the use of large valve overlap.

The use of an injection system giving injection into the cylinder also permits the use of fuel having a much wider range of distillation temperatures than aviation gasoline. In this country, where large supplies of fuels are available, this factor is not of great importance. In Germany, where the greater part of the fuel must be imported, the use of fuel-injection systems capable of handling a wide range of fuel volatilities has been selected as the method to be used on all military aircraft engines.

The military and naval services of the United States have been active in sponsoring the development of commercial fuel-injection systems. The National Advisory Committee for Aeronautics has limited its research to an investigation of the factors influencing the injection of fuel into the engine cylinder. These factors have included the location of the fuel-injection valve in the cylinder, the type of fuel spray to be used in a particular cylinder, the rate of fuel injection, the maximum injection pressure, and the time of start of injection.

Cylinders having a pent-roof combustion chamber with four valves and spherical combustion chambers with two valves have been investigated. In these cylinders, maximum performance has been obtained by directing the fuel to take advantage of the turbulence set up by the flow of air through the inlet valves. In the cylinder having the pent-roof combustion chamber, the best location of the fuel-injection valve was between the exhaust valves. The fan type of fuel spray was injected against the incoming air stream.

The number of possible locations of the fuel-injection valve in the cylinder having a spherical combustion chamber is limited. The best location has been found to be just above the steel barrel between the rear spark plug and the intake port.

The most important variables influencing performance have been found to be the location of the fuel valve, the type of fuel spray, and the airflow set up in the engine cylinder. Best results are always obtained with cylinders having either a high degree of air swirl or intense turbulence. If the cylinder has neither swirl nor turbulence, means must be furnished to set up air movement. In two-valve cylinders air movement may be obtained by shrouding the intake valves, by directing the intake manifold at an angle, or by changing the contour of the cylinder head.

The performance to be obtained with a modern air-cooled cylinder of approximately 200 cu.in. displacement when fitted with a carburetor, with a fuel system injecting into the manifold, or with a system injecting into the cylinder has been investigated by the Committee. The results obtained at a speed of 1900 r.p.m. with atmospheric pressure at the inlet are summarized in Fig. 1. The complete results of the investigation are given in reference 1.

The brake mean effective pressures obtained follow the curves of volumetric efficiency, being highest with injection into the cylinder and lowest with the carburetor. The minimum specific fuel consumption obtained with each method of atomizing the fuel was the same. Consistent firing could be obtained with leaner mixtures when using the carburetor than with either method of fuel injection. Since power output and minimum specific fuel consumption are the same, for all practicable purposes, other criterions must be used in determining which of the several systems of atomizing the fuel are to be used on a given engine.

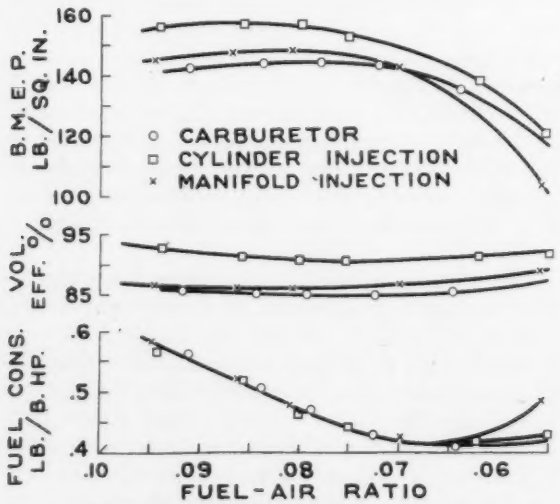

FIG. 1. Performance of cylinders with carburetor and two types of fuel injection.

SAFETY FUELS

In 1930 some products of the hydrogenation process, designated as "safety fuels," were made available.[2] These fuels had flash points of about 125°F. (Cleveland open-cup method) and distillation temperatures of between 325–400°F. The heating value of the fuel was 8 percent less than that of gasoline. The octane number of the hydrogenated safety fuel was 95 as determined by the manufacturer using a series 30 Ethyl Gasoline Corporation test engine operated at a speed of 600 r.p.m. and with a coolant temperature of 300°F.

These hydrogenated safety fuels were of particular interest to the Bureau of Aeronautics, Navy Department, because of their possible use in airship engines. The Committee investigated the performance to be obtained with these fuels in a cylinder having a pent-roof form of combustion chamber and found that the same maximum power could be obtained with safety fuel as with gasoline, but that the minimum specific fuel consumption was from 5 to 10 percent higher. The increased fuel consumption was accounted for, in part by the decreased heating value of the fuel.

New processes have recently become available[3] for manufacturing safety fuels having flash points of about 115°F. with heating values equal to that of gasoline. The performance to be obtained with these safety fuels is being investigated by the Commiteee on a single-cylinder engine using an air-cooled cylinder of approximately 200 cu.in. displacement. The injection system used is a single-cylinder unit of a commercially available multicylinder unit. The injection-valve opening pressure was 2000 lb. per sq.in.

The curves in Fig. 2 show a comparison of the engine performance obtained with two of these safety fuels as compared with that from technical iso-octane. The antidetonating qualities of the safety fuel being, at the present time, inferior to technical iso-octane, sufficient tetraethyl lead was added to the safety fuel to equal the antidetonating quality of the technical iso-octane. The performance of the safety fuel having a cut between 300–435°F. is the same as that obtained with technical iso-octane. The performance with the cut 400–635°F. was greatly inferior. Although the power could be made almost equal to that obtained with technical iso-octane, the fuel consumption was excessive. Any attempt to lean the mixture further than shown on the curves re-

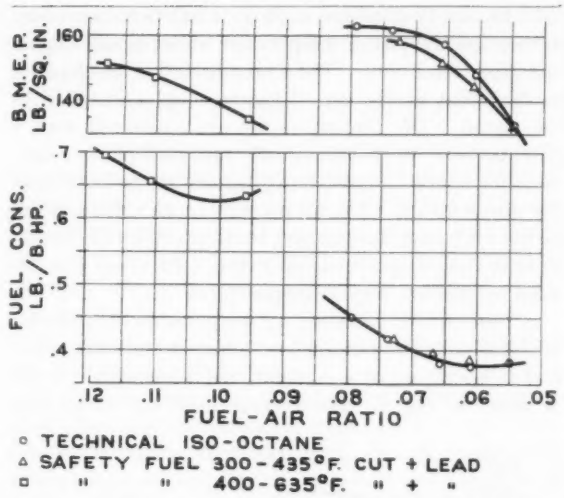

FIG. 2. Performance obtained with two safety fuels as compared with that from iso-octane.

sulted in misfiring. It is to be expected that every effort will be made by the fuel manufacturers to increase the octane number of these safety fuels, because their use should result in an appreciable reduction of the fire hazard in aircraft.

FINNING OF CYLINDERS

The modern air-cooled engine cylinder consists of a cast aluminum-alloy head screwed and shrunk onto a forged steel barrel. The cylinder is cooled by an air stream flowing over the finned surfaces of the cylinder. The dimensions of the fins on the cylinder head and barrel have usually been limited by casting and machining technique.

Eight years ago the Committee took up the problem of determining the effect of fin dimensions on the quantity of heat dissipated to an air stream. Since the first report[4] was published in 1934, numerous reports have been issued covering various phases of the problem. A final report summarizing the research will shortly be issued.

The criterions for selecting a fin design are usually the weight, the pressure drop available for cooling, or the power required for cooling. The three-dimensional surface shown in Fig. 3 shows the effect of fin spacing and fin thickness on the overall heat-transfer coefficient, U. This surface has been plotted for a pressure drop of 4 in. of water and a weight of steel fin of 0.127 lb. per sq.in. of wall surface. No limit has been placed on the fin width. At the peak position, the width of the fin is 1.29 in. It may be seen that, for the specified conditions, only one combination of fin space and fin thickness gives a maximum heat transfer. The variation from the maximum is small, however, for relatively large ranges of fin space and fin thickness.

The use of fins of copper, magnesium alloy, and aluminum alloy has been found to give about $2^1/_4$ times the heat transfer of steel fins for the same weight. It may be expected that serious considerations will be given to replacing the steel fins on the barrel to obtain improved cooling.

N.A.C.A. CLOSE-FINNED CYLINDER

The results obtained from the investigation of fin dimensions have been incorporated in the design of the N.A.C.A. close-finned cylinder. Fig. 4 shows a comparison between this cylinder and a conventional air-cooled cylinder having the same internal dimensions. The finned surface on the head of the new cylinder is six times and on the barrel is twice that of the conventional cylinder.

The space between the fins is 0.078 in., the fin thickness is 0.031 in., and the maximum width of the fin is

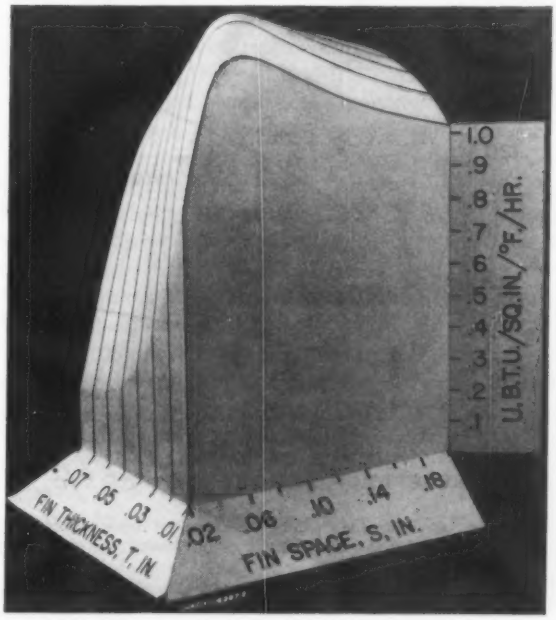

FIG. 3. Three-dimensional surface showing effect of fin spacing and thickness on overall heat-transfer coefficient U.

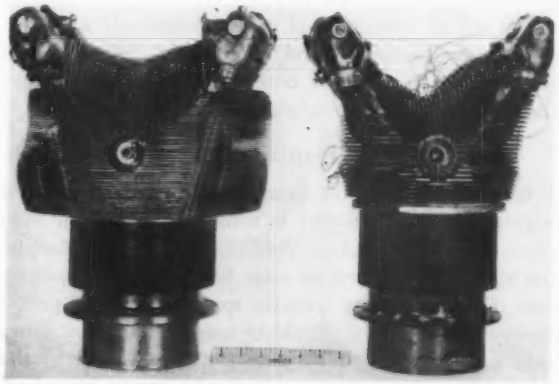

FIG. 4. Comparison of N.A.C.A. close-finned cylinder and conventional air-cooled cylinder with the same internal dimensions.

1.9 in. The dimensions of the desired fins prohibited the casting of the fins. A method was developed by the Committee in cooperation with the Norfolk Navy Yard for bonding preformed, sheet-aluminum fins to the cast aluminum alloy of the cylinder head.

This method of construction removes all restrictions with regard to dimensions of the cooling fins that can be used on the head and opens the way to more effective cooling and to further large increases in engine power.

The cylinder was mounted on a single-cylinder engine crankcase and tested to determine the possible power output and cooling to be obtained with this type of finning. The curves of Fig. 5 show a comparison of the indicated horsepower developed by the N.A.C.A. close-finned cylinder and by the conventional cylinder for an average temperature difference between the cylinder head and the cooling air of 300°F. The cylinder-head

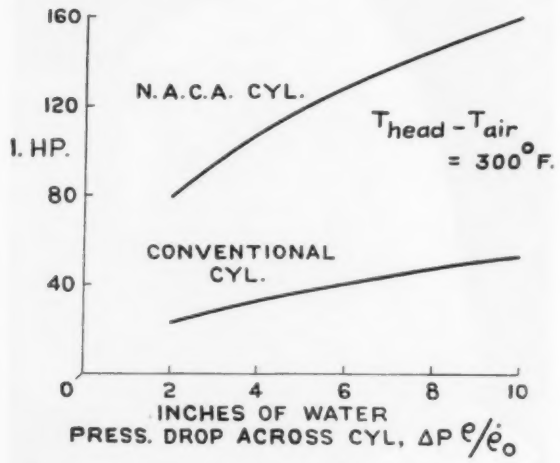

FIG. 5. Comparative values of indicated horsepower developed by N.A.C.A. close-finned cylinder and conventional air-cooled cylinder.

temperature was determined from the average of readings from 22 thermocouples located at corresponding points on both cylinder heads. The curves show that the N.A.C.A. cylinder will cool satisfactorily at 10 in. of water pressure drop when developing 160 indicated horsepower. This value is approximately three times the power of the conventional air-cooled cylinder.

SURVEY OF PISTON TEMPERATURES

With increase in the power obtained from a given engine cylinder, difficulty is usually encountered with piston and ring sticking. Additional cooling of the piston has been obtained on some high-output engines by directing an oil spray onto the under side of the piston crown. This method should be used on aircraft engines only as a last resort because the heat added to the lubricating oil can be removed only by the use of oil radiators. Increase in radiator size is reflected in increased weight and drag of the airplane structure.

In the study of piston cooling, it has been necessary to measure the piston temperature under actual engine operating conditions. The Committee has developed a method that makes use of thermocouples installed in the piston. The thermocouples are connected with a potentiometer by pneumatically operated plunger contacts for about 10 crankshaft degrees at the bottom of the piston stroke. The air pressure on the plungers can be released, and the plungers be dropped out of contact so that the equipment is operating only when it is desired to measure piston temperatures.

A plot of the variation in temperature distribution with fuel-air ratio obtained on a forged aluminum alloy piston operating in a conventional air-cooled cylinder is shown in Fig. 6. The average head and barrel tem-

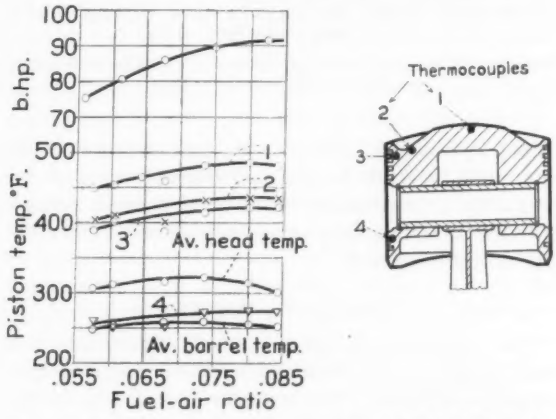

FIG. 6. Variation of piston temperature with fuel-air ratio for different thermocouple locations.

peratures are determined by averaging the readings of 22 thermocouples on the head and 10 thermocouples on the barrel. The aluminum alloy used in the piston has an ultimate tensile strength of 52,000 lb. per sq.in. at 100°F. and 11,000 lb. per sq.in. at 500°F. The rapid decrease in tensile strength of the aluminum alloy with increase in temperature has directed attention to other possible aluminum alloys having increased tensile strength at the operating temperature of pistons.

One of the most interesting points brought out by this temperature survey is the relatively low temperature difference between the average barrel temperature and the temperature of the piston skirt. In other tests, lowering the barrel temperature has been found to reduce the temperatures measured at all thermocouple locations on the piston. The results point to the necessity of studying all possible methods of improving the cooling of the cylinder barrel in order to lower the piston temperatures.

Considerable reduction in barrel temperature can be obtained by increasing the fin surface on the barrel. The fins on the barrel of the N.A.C.A. cylinder were formed from sheet steel and copper brazed to the cylinder barrel by the Pratt & Whitney Aircraft Com-

pany. This method of attaching the fins removes all restrictions as to the dimensions of the fins that can be used on the barrel.

Diesel-Engine Investigation

The theoretical and practical advantages of the Diesel engine for aircraft have been most thoroughly discussed in the literature. The principal arguments for the aircraft Diesel engine are: It would reduce the fire hazard; fuel consumption under cruising conditions would be lowered; and a relatively cheap fuel could be used. Inasmuch as the cost of fuel and oil represent 12 percent of the operating cost of an airline, any reduction in fuel cost is of extreme importance.

To be acceptable for airline use the Diesel engine must weigh approximately the same as the conventional Otto cycle engine, have the same take-off power, and have a lower cruising fuel consumption. At the present time, no available Diesel engine fulfills these specifications.

The research by the Committee on Diesel engines has been limited to the study of the fundamental factors influencing the injection and the combustion of the Diesel fuel. One of the most important results of this investigation has been the development of the N.A.C.A. displacer-type combustion chamber.[5] A cross-section of this combustion chamber adapted to an air-cooled cylinder is shown in Fig. 7. The cylinder assembly em-

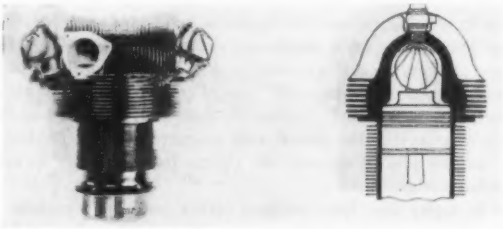

Fig. 7. A displacer-type combustion chamber adapted to an air-cooled cylinder. N.A.C.A. air-cooled Diesel cylinder; 5 in. bore × 5½ in. stroke.

ploys conventional materials and methods of construction. The cylinder head is of aluminum alloy screwed and shrunk onto a finned steel cylinder. The displacer is forged integrally with the aluminum-alloy piston.

The cylinder has been assembled on a single-cylinder crankcase and the performance has been determined for a range of engine speeds and boost pressures. The curves in Fig. 8 show the estimated performance of a 9-cylinder engine based on the measured performance of the single-cylinder engine. Curves are shown for a speed of 2200 r.p.m. and boost pressures of 2.5, 5.0, and 7.5 lb. per sq.in. The measured performance of the single-cylinder engine has been corrected for variation in engine friction, power required to supply combustion air, and the decrease in weight of charge caused by the temperature rise in the blower. The minimum specific fuel consumption of 0.36 lb. per b.hp.-hr. is obtained for a range of brake mean effective pressure from 100 to 120 lb. per sq.in. The minimum specific fuel consumption is obtained with 2.5 lb. per sq.in. boost pressure rather than at zero boost because of the improved scavenging obtained by operating with a large valve overlap and increased manifold pressure. For take-off, there would be available a brake mean effective pressure of 175 lb. per sq.in. The estimated weight of this Diesel engine would be 10 percent greater than the corresponding Otto cycle engine.

Unlike the 2-stroke Otto cycle engine, the Diesel engine presents no problem of obtaining satisfactory combustion of mixtures covering a wide range of fuel-air ratios. For this reason, the 2-stroke-cycle Diesel engine is particularly attractive as an aircraft power plant. The investigations of the Committee on the 2-stroke-cycle Diesel engine have been directed toward a study of the factors influencing the performance of a uniflow cylinder having piston-controlled inlet ports and poppet exhaust valves.

The background of practical experience available on the 2-stroke-cycle engine is extremely limited as compared with that on the Otto cycle engine. Engine variables being investigated by the Committee include the number, the shape, the timing, and the angle desired for the inlet ports; the lift and the timing of the exhaust valves; and the number arrangement, and location of the fuel sprays in an engine having a cylindrical combustion chamber.

A diagrammatic sketch of the N.A.C.A. 2-stroke-cycle Diesel engine and curves of performance obtained at 1800 r.p.m. with a scavenging air pressure of 10 lb. per sq.in. are shown in Fig. 9. The scavenging air is supplied by an independently driven blower. The "indicated power" curve has been corrected for the power required to supply the combustion and the scavenging air with a conventional blower to give the "net brake curve." At full load, a net brake mean effective pressure of 160 lb. per sq.in. is developed. The fuel consumption under this condition, which would correspond to take-off, is somewhat excessive but would be reduced to 0.42 lb. per b.hp.-hr. under cruising conditions.

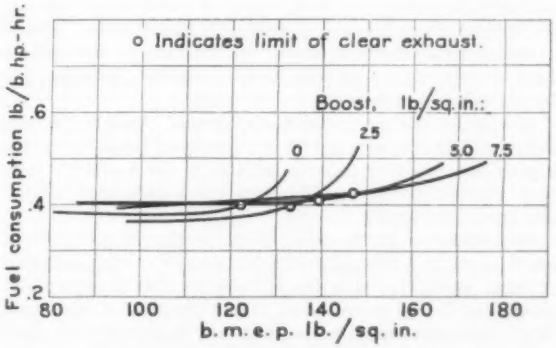

Fig. 8. Estimated performance of a 9-cylinder engine with displacer piston based on single-cylinder tests—engine speed, 2200 r.p.m.

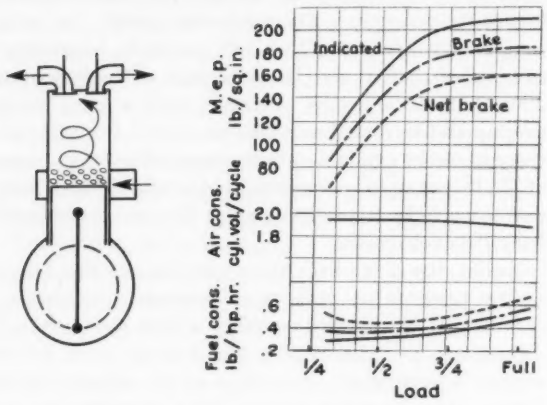

FIG. 9. Diagram and performance of N.A.C.A. 2-stroke-cycle Diesel engine; $4^5/_8$ in. bore × 7 in. stroke; 1800 r.p.m.

Because of excessive loads on the valve gear, which limit the maximum speed to about 2400 r.p.m., consideration is being given to the use of a sleeve-valve mechanism.

Sleeve-valve 4-stroke-cycle engines have received little attention in this country because of the satisfactory power outputs obtained from poppet-valve engines. For future 2-stroke-cycle engines it is believed, however, that a sleeve-valve mechanism will be of increasing importance.

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Book Review

The Modern Diesel; Iliffe and Sons, Ltd., London, fifth edition, 1938; 254 pages.

This compact little book offers very interesting reading to anyone interested in the progress of automotive type engines and trends toward types.

In spite of limited space the authors have found room for enough descriptive matter on the subject of fuel-injection pumps to satisfy most readers' desire to know quite fully just what this thing is which supplants carburetor and electric ignition in a type of engine now being quite broadly accepted as a good prime mover.

Of course, one may feel it is a bit early to state that in comparison the (injection) "apparatus is simple," for that might be quite honestly questioned by operators and particularly fleet operators who have had or are still experiencing difficulty in accustoming service personnel to a new type of engine accessory as critical of adjustment and supercritical of cleanliness as is fuel-injection equipment. This is without question one of those transitions which experience will iron out.

The subject matter proceeds logically from injection systems to cylinder-head design and many types of combustion chambers are thoroughly explained as to construction and action. It may be assumed that since the size of the book and its title will attract readers entirely outside of the automotive industry, this section will be gratefully received by many.

Descriptive matter covering combustion chambers is also well spread into the next section on "Transport Engines," so that a good understanding is made possible of the variations from basic types of combustion chambers which have been adopted and proved serviceable.

One criticism might be offered on this section, however. Inasmuch as the M.A.N. engine with its "air cell" type combustion chamber was a very early one to enter the road transport field, many readers may so remember it, and the detailed description of its combustion process be read with considerable interest. Consequently, the statement that, . . . "Upon ignition the air compressed in the cell is directed into the burning mixture expelled from the combustion chamber . . .", may be unfortunate. Even lay readers will wonder how air at compression pressure in the cell can possibly be expected to flow out against the pressure of an ignited fuel-air mixture. . . "upon ignition."

The performance figures given for the many commercial engines in all the various fields give a good idea of power sizes offered but only in a few instances is the specific output (B.M.E.P) given. Since the authors more or less take the position of exponents of the "open chamber" type of engine, it would be almost expected that B.M.E.P. ratings be somewhat exploited as they proceed with the description and characteristics of production line engines and so support the claims for advantage in open-chamber design.

It is hoped that later editions of the book may include the "tractor" application of oil engines which surely offers material for a good round chapter.

Divergence from the exact subject sufficiently to take in the Hesselman type engine, a well-chosen parenthesis because of the wide use which this type has found, is testimony to that sort of research which finds a good workable compromise during a trend toward radical change. This engine will, no doubt, always be looked back to as "filling a gap" which permitted many operators the advantage of low priced fuel oil while it was still so priced without investing in the earlier and costlier "full Diesel" engine.

All told the present new edition of "The Modern Diesel" is to be recommended as good reading for any mechanically inclined person, engineer or layman, since it presents a comprehensive picture of the types of these engines which are being used in the smaller sizes for various purposes.

The book may well have a somewhat de-bunking effect on that part of the reading public interested in the subject, for without a doubt the Diesel has been more loudly than accurately publicized during the past three or four years.

The subject is discussed honestly and explicity in all its aspects and it is splendidly presented and well illustrated by both photoplate and the admirable line drawing perspective.

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Laminar Frictional Resistance with Pressure Gradient

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United States Navy

THE increasing importance of an extended laminar flow region in reducing the total frictional drag of a body has stimulated investigation of the effect of various influences, including the pressure (velocity) gradient outside of the boundary layer. In addition to altering the Reynolds Number of transition, pressure gradient has considerable influence on the coefficient of local friction, for the calculation of which a simple method is highly desirable.

For the purpose of conducting a fundamental investigation of the effect of pressure gradient, a boundary layer research tunnel, sponsored by the National Advisory Committee for Aeronautics, was constructed at the Massachusetts Institute of Technology. Test data from this tunnel for zero pressure gradient (constant potential velocity) have been discussed recently by Peters.[1]

Theoretical Treatment

von Kármán's momentum theorem of the boundary layer[2] states that the friction between a fluid and a solid is accompanied by an equivalent change of momentum carried by the fluid. For the boundary layer with pressure gradient, the equation takes the form

$$\frac{1}{U}\frac{d}{dx}\int_0^\delta u\,dy - \frac{1}{U^2}\frac{d}{dx}\int_0^\delta u^2\,dy = \frac{1}{\rho U^2}\delta\frac{dP}{dx} + \frac{\tau_0}{\rho U^2} \quad (1)$$

where

x = distance from the leading edge, measured along the surface
y = distance normal to the surface
U = velocity in x direction at any point outside of the boundary layer
u = velocity in x direction at any point inside of the boundary layer
δ = thickness of the boundary layer; as $u \to U$, $y = \delta$
τ_0 = shearing stress at $y = 0$
ρ = mass density of the fluid.

The static pressure P varies with x and equals the pressure of the potential flow outside of the boundary layer, so that pressure and velocity gradients are associated by the relation

$$\frac{dP}{dx} = -\frac{\rho}{2}\frac{dU^2}{dx} = -\rho U\frac{dU}{dx}$$

Employing this relation and letting

$$\theta = \int_0^\delta \left(\frac{u}{U} - \frac{u^2}{U^2}\right)dy \text{ and}$$

$$\delta^* = \int_0^\delta (1 - u/U)dy, \text{ Eq. (1) reduces to}$$

$$c_f = \frac{\tau_0}{{}^1/_2\rho U^2} = 2\frac{d\theta}{dx} + 2\theta(2 + (\delta^*/\theta))\frac{dU}{Udx} \quad (2)$$

where

c_f = coefficient of local friction
θ = momentum thickness
δ^* = displacement thickness.

From Eq. (2), it is apparent that the coefficient of local friction c_f is fully determined by the variables θ, δ^*, and U. The velocity of the potential flow U is calculated from the static pressure gradient. The parameters θ and δ^* depend entirely upon the velocity distribution inside of the boundary layer.

Pohlhausen has developed equations for the velocity distribution in the laminar boundary layer by an approximate solution of Prandtl's differential equations. Exact solutions of Pohlhausen's equations for the particular case $U = kx^m$ have been obtained by Falkner and Skan. According to Dryden,[3] who has thoroughly reviewed the theoretical treatment, the exact solutions compare satisfactorily with experimental data only for negative pressure gradients where $\lambda = \frac{\delta^2}{\nu}\frac{dU}{dx}$ is less than 10. To determine the parameters of von Kármán's momentum equation, the solutions for the velocity distribution have been integrated to give

$$\delta^* = \delta\left(\frac{3}{10} - \frac{\lambda}{120}\right) \quad (3)$$

$$\theta = \delta\left(\frac{37}{315} - \frac{\lambda}{945} - \frac{\lambda^2}{9072}\right) \quad (4)$$

$$\delta^*/\theta = \frac{3/10 - \lambda/120}{37/315 - \lambda/945 - \lambda^2/9072} \quad (5)$$

Experimental Methods

The boundary layer research tunnel is of the pressure type with open room return. Fine wire screens, a

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The authors wish to express their appreciation to Prof. H. Peters, who is in charge of the boundary layer research program at M.I.T., for his advice during the course of the investigation.

honeycomb, and a sharply converging section serve to smooth the flow so that the air entering the test section has a uniform velocity distribution and not greater than 0.5 percent fluctuation. A slot at the leading edge of the polished steel test plate is adjusted to produce stagnation at this point. By positioning an adjustable back opposite the test plate, various pressure gradients are obtained. Fig. 1 illustrates the arrangements of the back for the two parabolic pressure gradients employed in these experiments:

$$\text{Positive gradient } \frac{P - P_1}{\rho/2U_0^2} = +0.0634\ [\sqrt{x} - 3.23]$$

$$\text{Negative gradient } \frac{P - P_1}{\rho/2U_0^2} = -0.0605\ [\sqrt{x} - 2.68]$$

where

x = distance from leading edge in inches
$P - P_1$ = static pressure difference between test station and station 1
$^1/_2\rho U_0^2$ = dynamic pressure in the free stream at leading edge.

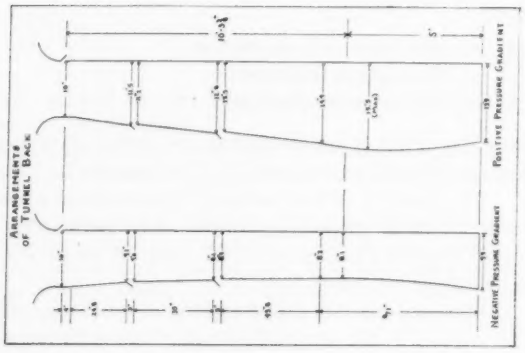

FIG. 1.

Velocity measurements within the boundary layer are obtained by means of a small goose-neck pitot tube in conjunction with a traversing mechanism which measures to 0.01 mm. Velocity profiles, samples of which are indicated in Figs. 2 through 5, were determined at selected stations along the test plate for each of three basic velocities U_0, namely: 37.8, 59.8, and 85.0 ft. per sec. Graphical integration of the various velocity profiles furnished the values of the experimental parameters θ and δ^*.

DISCUSSION OF RESULTS

While investigating separately the variables in Eq. (2), it was observed that, with pressure gradient, $2\theta/x$ was a function of the local Reynolds Number Ux/ν. Further investigation disclosed that $2\theta/x$ was a unique function of Ux/ν for nine experimental conditions: A positive, a zero, and a negative pressure gradient, each with three basic velocities. Blasius has derived theoretically an expression for the coefficient of total friction for zero pressure gradient,

$$C_f = \frac{1.328}{\sqrt{U_0 x/\nu}} \tag{6}$$

Replacing C_f by its equivalent $2\theta/x$ and plotting against $1/\sqrt{Ux/\nu}$ (where $U = U_0$ for zero pressure gradient), the Blasius equation appears as the straight line of Fig. 6. The corresponding values for the experimental

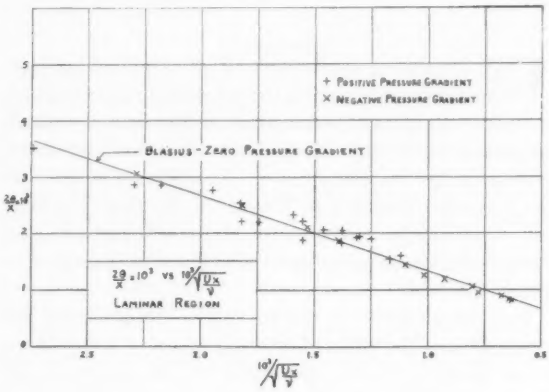

FIG. 6.

pressure gradients are observed to follow closely the Blasius line for zero pressure gradient. The experimental values for zero pressure gradient were defined by the Blasius equation, except for a slight rise where the positive pressure gradient points also tended to be above the line. The conclusion reached from a study of the experimental evidence of Fig. 6 is that, for the range of pressure gradients employed,

$$\frac{2\theta}{x} = \frac{1.328}{\sqrt{Ux/\nu}} \tag{7}$$

The ratio of displacement thickness to momentum thickness, δ^*/θ, was found to be approximately independent of the local Reynolds Number. Experimental values of δ^*/θ are plotted in Fig. 7, except zero pressure gradient for which the average value was 2.38. Fig. 7 indicates that the ratio δ^*/θ varies with pressure gradient. However, the ratio appears only in the term $(2 + \delta^*/\theta)$ in Eq. (2) and, for engineering purposes, may be taken as a constant for all pressure gradients. A suit-

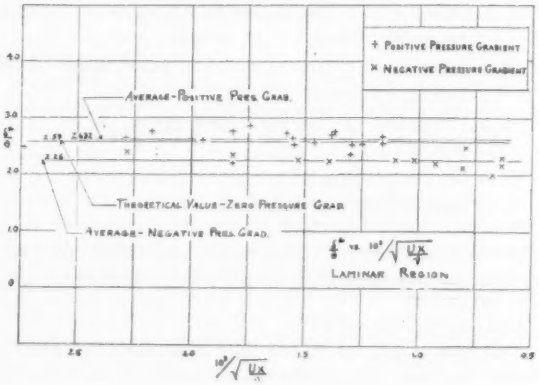
+ POSITIVE PRESSURE GRADIENT
× NEGATIVE PRESSURE GRADIENT
AVERAGE - POSITIVE PRES. GRAD.
THEORETICAL VALUE - ZERO PRESSURE GRAD.
AVERAGE - NEGATIVE PRES. GRAD.
LAMINAR REGION

FIG. 7.

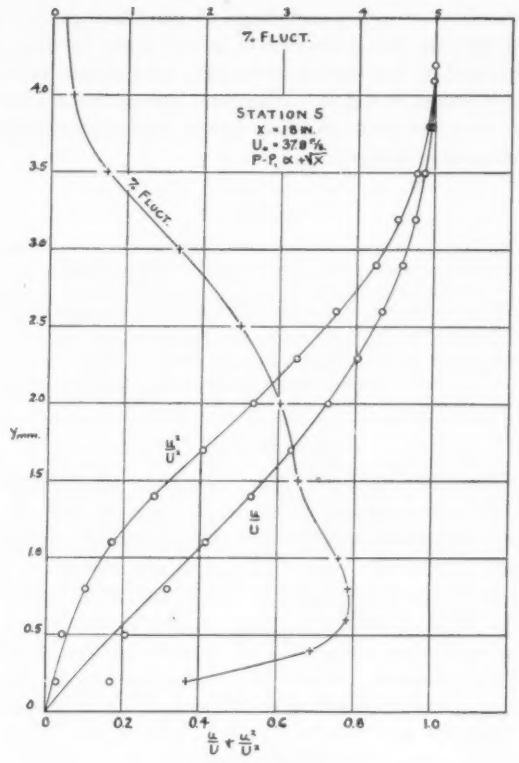

FIG. 2.

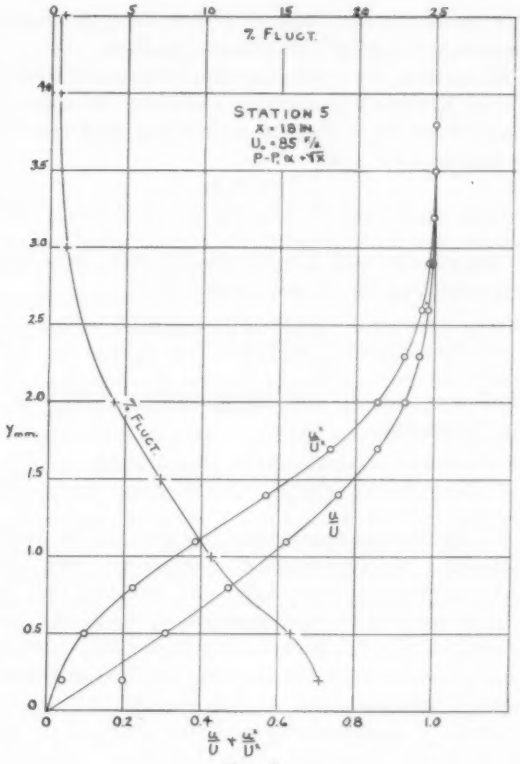

FIG. 3.

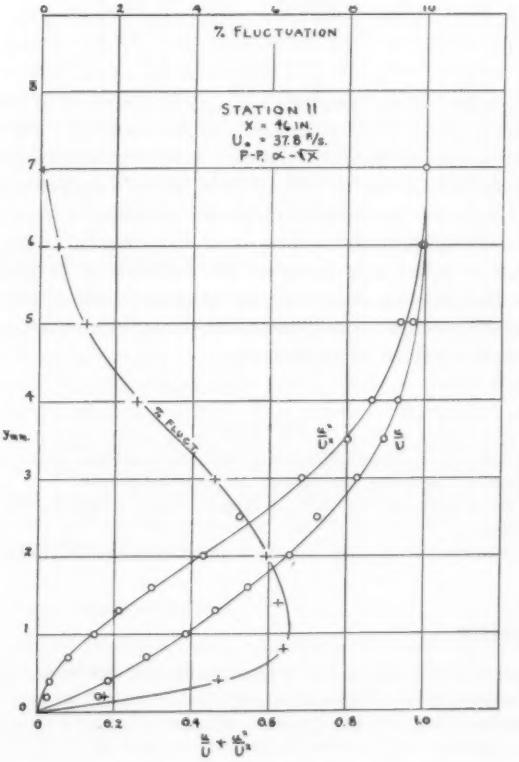

FIG. 4.

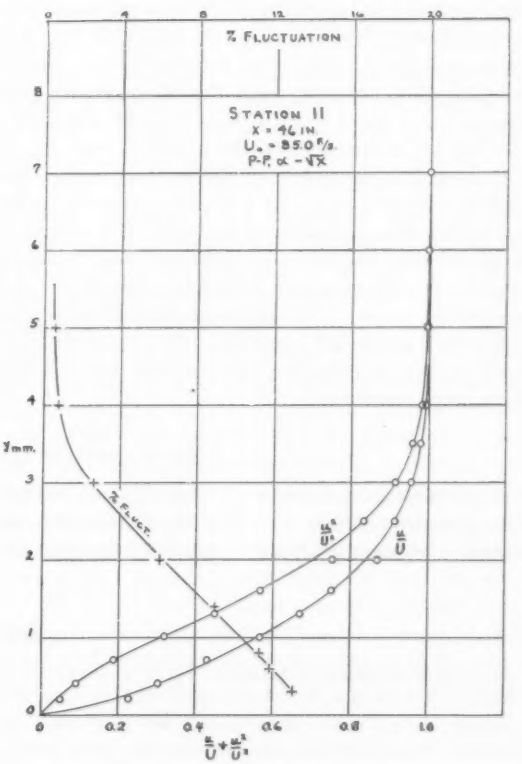

FIG. 5.

able choice for the value of δ^*/θ is 2.59, the Blasius theoretical value for zero pressure gradient.

All variables are now in the form for a general solution of von Kármán's momentum equation. It was concluded from Fig. 6 that the momentum thickness may be expressed by

$$\theta = \frac{0.664x}{\sqrt{Ux/\nu}} \tag{8}$$

in which both x and U are variable for the same fluid. Differentiating Eq. (8) with respect to x,

$$\frac{d\theta}{dx} = \frac{0.332}{\sqrt{Ux/\nu}}\left[1 - \frac{x}{U}\frac{dU}{dx}\right] \tag{9}$$

Employing Eq. (9) and assuming that $\delta^*/\theta = 2.59$, Eq. (2) becomes

$$c_f = \frac{0.664}{\sqrt{Ux/\nu}}\left[1 + 8.18\frac{x}{U}\frac{dU}{dx}\right] \tag{10}$$

The Pohlhausen approximate solution may be used to investigate the experimental conclusions. The theoretical expression for δ^*/θ, Eq. (5), indicates that this ratio varies with pressure gradient, as observed experimentally in Fig. 7. However, for the limiting condition when λ is equal to 10, the variation in δ^*/θ from the zero pressure gradient value of 2.55 is only 10.6 percent, which has a comparatively negligible effect on the precision of the coefficient of local friction. Moreover, Eq. (8) states that, at a particular distance x from the leading edge, θ depends only upon the local Reynolds Number and is independent of the local pressure (velocity) gradient. However, Eq. (4) indicates that θ depends upon both δ and λ, but fortunately the variation is small. For example, with the experimental conditions of Fig. 5 and $\delta = 5.5$ at $u/U = 0.998$, the value of θ by Eq. (4) is the same as that obtained from Eq. (8).

In regard to the extent of the laminar region, these experiments indicated that a positive pressure gradient accelerates the occurrence of transition and reduces the range between laminar and turbulent flow, whereas a negative pressure gradient delays the transition and increases the range. The approximate ranges of transition in the tunnel with approximately 0.2 percent turbulence in the undisturbed flow outside the boundary layer, were as follows:

	Local Reynolds Number
Positive pressure gradient	700,000 to 1,000,000
Zero pressure gradient	2,000,000 to 3,000,000
Negative pressure gradient	2,500,000 to 4,000,000

This effect on point and range of transition is clearly indicated by the curves of root mean square fluctuation (obtained by hot wire anemometer) for constant values of y/θ, shown in Fig. 8. In general, the percent fluctuation near the plate increases before transition velocity profiles are observed.

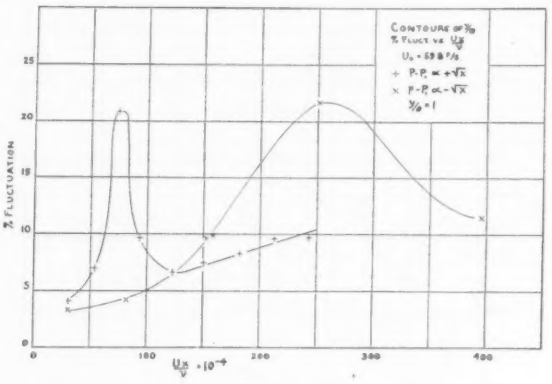

FIG. 8.

Conclusions

The equation

$$c_f = \frac{0.664}{\sqrt{Ux/\nu}}\left[1 + 8.18\frac{x}{U}\frac{dU}{dx}\right]$$

provides a direct method of including the effect of pressure gradient in the calculation of the coefficient of local friction in the laminar boundary layer. A study of the experimental results and of Pohlhausen's approximate solution for the velocity distribution indicates that, although simplifications have been introduced, the equation is sufficiently accurate for engineering purposes. In defining the extent of the laminar boundary layer, the effect of pressure gradient on the point and range of transition must be considered.

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Book Review

Practical Mathematics of Aviation, by A. E. Downer; Pitman Publishing Corporation, New York, 1939; 107 pages, $1.00.

Starting with a review of arithmetic, this book takes up, in succession, simple algebraic equations, graphs, ratio, proportion and percentage, the right triangle, and a few of the more simple applications in mechanics. A large number of problems and questions are given. These are for the most part of an aeronautical nature. The text and problems are adaptable to a high school or aviation school course in mathematics and the book should serve admirably as a text for such a course.

Airplane Demagnetization and Neutralization

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ABSTRACT

The causes of airplane magnetization are discussed together with means for eliminating or correcting them. Emphasis is placed on the limitations of the conventional methods of demagnetization and on the advantages of neutralization of large and awkward structures. A description of the neutralization method is given. Data are presented illustrating the permanent effects obtained by the neutralization method.

INTRODUCTION

THE aeronautical engineer is occasionally confronted with an airplane, or major part thereof, which has become so strongly magnetized that the compass deviation exceeds the usual 12° limit. Despite the trend toward aluminum alloy construction, large masses of steel are employed in engines, engine mounts, armament, and accessories, and the steel tube fuselage is still in general use in the smaller airplanes. These steel parts are frequently subjected to magnetic inspection in the process of their manufacture. If they are not completely demagnetized before being incorporated in the airplane, violent compass deviations are likely to ensue.

If a magnetized airplane is found to be free from stray electric currents and is fitted with a compass of known accuracy, and if a preliminary investigation fails to disclose any easily removable magnetized object, a general magnetic survey of the airplane is in order. Since the average aeronautical engineer seldom specializes in magnetic phenomena, the following notes may be of value before beginning the survey.

Definition of a North Pole

As it is known that like poles repel and unlike poles attract, the "North," or properly "North-seeking," pole of the compass and the earth's "North magnetic pole," which attract each other, must actually be of opposite polarity. This inconsistency can be clarified if it is remembered that the *North-seeking end of a compass needle* (usually colored blue) *always points to a South pole*, and that the earth's "North magnetic pole," which is located near the North geographic pole, is actually a "South" pole.

Induced Magnetic Effects

All steel members tend to pick up induced magnetism from the earth's magnetic field, and hence affect a compass. Thus a steel tube lying north and south will appear to have a "North" at the northerly end. If the tube is turned end for end, the "North" should still be at the northerly end, *i.e.*, the polarity of the tube will have been reversed. This indicates that the tube is not magnetized in itself, but is merely exhibiting induced magnetism from the earth's field. If, however, turning the tube end for end should move the "North" pole to the southerly end, or should greatly modify its strength, then the tube itself is magnetized.

The earth's magnetic field has a vertical component, varying from zero near the equator to a maximum near the poles. In most parts of the United States this component is actually stronger than the horizontal component. Hence, all vertical members of appreciable length tend to show a "South" pole on top. Turning the member end for end still gives a south on top, unless the member itself is magnetized.

Strength of a Pole

The strength of a unit magnetic pole is usually defined by saying that if two unit poles are placed one centimeter apart, the force between them is one dyne. Also, the strength, or intensity of a magnetic field is usually defined as the force, in dynes, which would act on a unit pole if it were placed in the field, and is expressed in gausses. Unfortunately both these definitions are inconvenient for the airplane designer. They require the use of an instrument actually calibrated in absolute magnetic units, or at least a "standard" magnet of some type.

A much more convenient, although admittedly less scientific, method is to determine the *comparative* strength of a magnetic pole in relation to the local strength of the earth's field. This may be done by holding a small pocket compass near the pole to be investigated, and gradually moving it away. As the compass moves away from the pole, there comes a point, for example, six inches from the pole, where the field of the pole is exactly equal and opposite to the earth's field. At this point the compass tends to point east and west, or lacks all directive tendency. The distance from the pole to this point is a measure of the strength of the pole compared with the strength of the earth's field, and the pole may be described as "having a strength of six inches." Note that the compass should be held on the south side of a north pole and on the north side of a south pole. Also, since magnetic force varies with the square of the distance from the pole, a pole of "six inches strength" is four times as powerful as a pole of "three inches strength."

If at some later date it is desired to determine the absolute field intensities of the poles it will be only

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necessary to determine the strength of the earth's field or, rather, its horizontal component at the place where the measurements were made. For the great majority of cases it is not necessary to know the absolute field intensities.

Magnetic Survey of an Airplane

A systematic exploration of an airplane may be undertaken with a small pocket compass. This can be done inside a building, provided the airplane is not too near steel structure. The airplane may be complete or in skeleton form only, for cloth covering and aluminum alloy sheet are non-magnetic and do not act as "shields." It is advisable to have the axis of the principal steel members of the airplane on an east and west heading to reduce the earth's induced effect in the long members.

In the event that the magnetized object is part of the built-in structure, and not removable, a record should be made of pole strengths at all points adjacent to the compass. It can be shown that all poles of "5 inches strength," or less, at a distance of 36 inches from the compass, or more, will give less than 1° deviation and can therefore be neglected. In steel tube fuselages it will often be found that one end of a magnetized tube is close enough to a compass to affect the reading, while the opposite end, which is equally strong, is far enough away to be neglected. Another frequent occurrence is that two or more tubes will have their common poles meeting in a joint, while their opposite poles will be separated, thus producing, for example, a single strong north, and several weaker souths, as in Fig. 1, where the compass at *A* is strongly affected by the south at the top of pyramid *B* in which several magnetic members meet, while the opposite ends of these same members are too far from the compass to give any compensating effect.

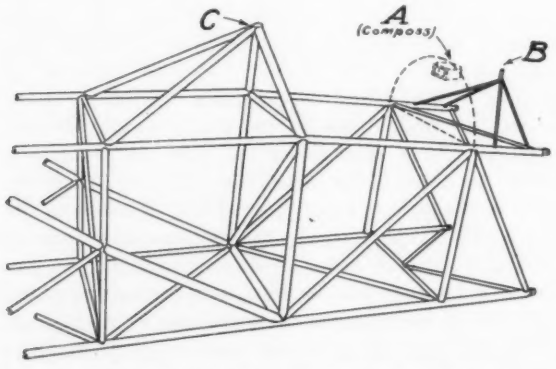


Fig. 1. Typical fuselage and compass installation.

On the other hand, the larger pyramid at *C*, when equally strongly magnetized, is too far from the compass to cause difficulty.

Having determined the source of the magnetic disturbance, the question arises whether to eliminate the difficulty by demagnetization or by neutralization. Generally speaking, compact units, or long slender parts can best be demagnetized. Complex structures of large dimensions or awkward shape can best be neutralized, for the reason that their size makes them subject to appreciable induced magnetism from the vertical component of the earth's field, and any attempt to demagnetize them only serves to make permanent this induced magnetism. Likewise, it has not been found practical to demagnetize a small integral part of a large unit. Such parts must be neutralized.

Demagnetization

Demagnetization by means of an alternating electric current is a familiar process. It consists of passing an alternating magnetic flux through the piece, gradually reducing the intensity to zero. With each "wash" of the flux through the piece, the polarity is reversed, the strength of that polarity depending upon the strength of the alternating flux. As the flux gets weaker with each alternation, the polarity weakens until finally the piece becomes entirely demagnetized.

The most convenient alternating magnetic flux is that produced with a hollow coil carrying an alternating current of constant amplitude. The piece is passed through the coil and removed to a considerable distance before the current is turned off. This results in a gradually diminishing magnetic flux as the piece leaves the influence of the coil. At 60 cycles a second, the piece can be passed through with considerable rapidity. The piece should be checked with a pocket compass after it has passed through. It may require a second pass.

The size of coil depends upon the size of the work and the permeability of the material. One successful coil used for demagnetizing tubing consists of an oval tube of sheet aluminum $4^1/_4$ by $6^3/_4$ inches and 30 inches long, surrounded by 180 turns of No. 6 insulated wire, carrying 30 amperes with 110 volts a.c. impressed upon it. This coil will handle $1^1/_2 \times 0.095$ chrome-molybdenum steel tubing with fittings welded on, in lengths up to 20 feet or more. It should be remembered that the larger the coil opening, the greater must be the number of ampere turns in the coil to produce the same strength of magnetic flux.

When handling long or heavy pieces, the axis of the coil should always be placed in an east-and-west direction. Otherwise, the earth's field will add to the flux of the coil, increasing it in one direction, and decreasing it in the other, with the final result that a piece passing through it will become magnetized instead of demagnetized. Similarly when checking a long or heavy piece with a pocket compass, the axis should always be east-and-west.

Another method of producing an alternating magnetic flux is the "growler," which is nothing but an alternating current electro-magnet having a small gap in the iron core. This gap is moved gradually over and

around all portions of the piece, and slowly withdrawn. While the "growler" will handle certain awkward structures, such as engine mounts, better than anything else, it is difficult to use, because the magnet tries to grip the piece, and once in contract it is almost impossible to remove it slowly. The piece must be checked subsequently with a pocket compass for local poles, as well as general magnetism.

There is a definite limit to the cross-section which may be demagnetized by the alternating current method. The vertical component of the earth's field, unlike the horizontal component, cannot be avoided by turning the work east-and-west. The vertical component is always present. Thus when the vertical dimension of a piece exceeds approximately 30 inches, it cannot be demagnetized by ordinary means. An attempt to demagnetize a finished airplane having the fuselage shown in Fig. 1, is an instructive example. The fuselage was wound with 1000 feet of No. 6 insulated wire, and by means of some very heavy equipment the current was gradually varied from 0 to 200 amperes and back to zero. An impressed voltage of 400 volts was required, and some 14,000 ampere turns provided. Large adjustable transformers were employed to gradually reduce the current in the coil. With this powerful equipment the original magnetic field of the fuselage was destroyed, but a new field was built up by the vertical component of the earth's field, added to the alternating field of the current. A south pole was established throughout the upper longeron and the tops of the vertical members, with a corresponding north pole at the lower longerons. The general intensity was at least as great as before treatment.

Neutralization

The Neutralization Method, which was developed at the Chance Vought Aircraft Division of the United Aircraft Corporation, from an initial suggestion by Prof. A. V. deForest of M.I.T., does not have these limitations. It consists of selecting the most powerful poles adversely affecting the compass and reducing the strength of these poles by means of a direct current coil.

A piece of unmagnetized steel or iron may be conveniently pictured as being made up of a great number of tiny magnetic particles arranged at random, so that no net magnetic field is produced. When such a piece is subjected to the magnetic field of a coil, many of these tiny magnets are brought into alignment, thus making the piece a "permanent" magnet. Many more tiny particles are partially aligned, in a state of unstable equilibrium. These produce an "impermanent" magnetism, which may be lost over a period of time, especially if vibration is present. It has been found that if the piece is vigorously hammered while the direct current is being applied to the coil, a great number of these tiny magnets are shaken into stable position, and the piece becomes much more strongly magnetized than without hammering. However, even this leaves a large number in the unstable condition. If the piece is subsequently hammered with the current off, the latter unstable particles are shaken back into a stable condition, which slightly weakens the field. When tested with an exploring compass, the first hammer blow will be seen to produce the greatest effect. Each subsequent blow produces less, until finally continuous hammering will produce no further change at all.

Since each pole is accompanied by a corresponding, but opposite pole at the other end of the member, the entire member acts as a magnet and must be demagnetized as a unit. If the member is wound as uniformly as practical with a coil of No. 14 insulated wire, spaced roughly 1 inch between turns, and the ends of the wire connected in series with a variable resistance, an ammeter, a reversing switch, and a common 6 volt automobile storage battery (Fig. 2), the member can be magnetized or demagnetized as desired. Following the

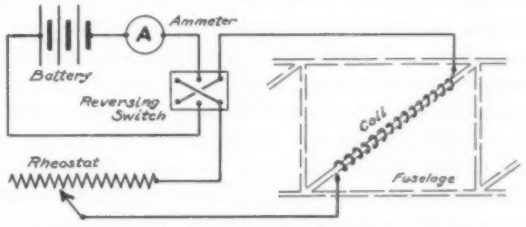


Fig. 2. Wiring diagram, neutralization method.

"right hand rule" and assuming the current flowing from negative to positive, if the member is grasped with the right hand, the fingers pointing around the member in the direction the current flows in the coil, the thumb will point in the direction of the South pole (the pole which attracts the "North-seeking" pole of the compass). A small initial current passed through the coil may be noted on the compass, and its effect checked before applying the main current.

Since the direct current apparatus is portable, it can be taken to the compass "rose" where the airplane is being swung. The airplane is put on the heading which shows the greatest deviation. The member to be demagnetized is wound with wire, and a small current applied without removing the regular compass from the airplane. With the current on, the member is hammered vigorously with a mallet. Striking the member laterally, near its midpoint is much more effective than striking endwise. The mallet should be used with discretion, as small steel tubes can be damaged by too much enthusiasm. While the member is being hammered, the compass should be watched, more current and hammering being applied until the compass card has been brought 5° or 6° beyond the desired reading. The hammering should be continued with the current off until additional hammering fails to reduce the compass reading further.

Some judgment is necessary in this work. If the magnetic disturbance consists of a single tube, as above, the problem is simple. If the disturbance is a cluster of converging tubes, or a pyramid, it is advisable to wind all the tubes at one time, connect them in series, and treat them simultaneously. Often it can be seen that demagnetizing any given member will not produce the desired change. In this case it is convenient to head the airplane on one of the cardinal points and partially correct the compass on this heading, then swing to a point at 90°, and using another member, partially correct the compass on that heading, until after several steps the desired results are obtained.

One advantage of the neutralization method is its great convenience, and the fact that it does not harm the compass in the airplane. With careful use of the rheostat, the compass will not show any violent jumps, and it may be left in the airplane during the entire procedure, with the result that the engineer knows at all times just how much correcting he has done. As long as the process is used to *demagnetize* members, it is obvious that the local magnetic field in the airplane will be less than before. However, the process may also be used to magnetize members and produce a new field in opposition to the old local field in the airplane. This should be avoided, because the building up of opposing local fields weakens the directive force of the earth's magnetic field, and is obviously no better than the excessive use of the compensating magnets in the compass base. Only when the magnetic disturbance is weak, and is made up of many magnetic members, is it advisable to carry the neutralization of a single member past the zero point to build up an opposing field.

Permanence of Neutralization Treatment

The subject of permanence is of major importance. It raises two questions. Will the corrective "neutralization" of members fade out, or will the original field fade out, leaving the correction in the structure? Any magnetic arrangement of particles is stable, provided it has been subjected to sufficient vibration to cause the unstable particles which were "on the fence" to align themselves in one direction or another. By the time an airplane is built, it has been subjected to much hammering, which is generally, but not always, sufficient to make permanent whatever local magnetic field may have been built into it. To make sure, it is not advisable to swing the compass or attempt correction until after ground test, which usually involves an hour of engine operation. Any airplane which has had an hour of flying or engine running on the ground has usually shaken itself into a state of permanence. The applied correction is also permanent, if the members were adequately hammered.

Experience over a three months' operating period, with 16 compasses on which records are available, showed a maximum recorded change of approximately 2.0°. A typical example is shown in Table 1, for the rear compass of a recent two-seater Navy airplane. Line *A* gives the compass readings on the airplane as first swung on the compass "rose." Line *B* shows the changes accomplished by neutralization, which amount to 20° maximum. Line *C* is the same as line *B* except that the engine is running, which shows a maximum difference of only 1°. Line *D* is also with the engine running, but the compass has now been compensated with its self-contained compensating magnets (6° maximum change). Line *E* is identical to *D* except it was taken after three months of service use. Note that only a 2° change has occurred between *E* and *D*. The accuracy of the readings is of the order of ±1°.

Prevention of Magnetic Effects

Magnetic effects on the compass can be avoided by demagnetizing all raw material going into the airplane and by a systematic check with a pocket compass of all finished assemblies. In the detail design of the airplane care must be taken that all electric wires be enclosed in metal conduits, those near the compass being composed of twisted pairs, and that large masses of steel, or long steel members be kept as far from the compass as is practical.

When magnetic material is once in a factory, it is quite difficult to trace, because nearly all airplane jigs and storage bins are large enough to have strong induced effects from the earth's field, some of which have become permanent due to continued hammering in the course of manufacture of the airplanes. However, a survey can be made of fabricated parts, carefully checking the strength of their poles at each stage of manufacture.

Such a survey at the Vought plant led to the discovery that trouble lay in the fuselage department and the stock room. A considerable quantity of magnetized tubing was on hand, whose presence was at first overlooked because the tubing bins lay directly north and south, and hence all the tubing exhibited a strong induced field. The tubing was actually magnetized, as

Table 1

Typical Effect of Neutralization on Compass

True heading	360	30	60	90	120	150	180	210	240	270	300	330
A (as built)	344	20	60	102	137	168	194	219	241	265	289	315
B (neutralized)	359	27	55	85	117	149	183	215	246	275	304	331
C (engine on)	358	..	..	86	..	..	184	..	..	274	..	..
D (compensated)	1	30	60	90	119	150	180	210	241	271	302	332
E (3 months)	1	30	60	91	121	151	181	210	242	272	302	332

could be shown by removing it from the racks and placing it east-and-west. When this tubing was cut, and the ends machined, the vibration thus produced appeared to make it even more strongly magnetic than before. Subsequent welding had no further effect upon it. Demagnetization of the tubing remedied this difficulty.

The elimination of induced magnetism from a complicated structure is not easy, but can be accomplished in various ways. In Fig. 1, for example, the chrome-molybdenum tubular pyramid at *B*, which was about 4 inches from the compass, was replaced by a stainless steel pyramid (18-8) which is ordinarily non-magnetic. Taking a group of 12 airplanes, as originally built, the maximum compass error averaged 22.7°. Replacing the pyramid *B* with stainless steel, and thoroughly demagnetizing the fuselage tubing resulted in an average for 12 subsequent airplanes of only 7.5°, the improvement in this instance being due largely to the elimination of induced magnetism at *B*. Generally speaking, the only cure for induced magnetic effects near the compass is to replace the steel member with a non-magnetic one—brass or aluminum alloy preferred. 18–8 stainless steel is usually non-magnetic, although instances are recorded of its being magnetized, dependent upon the amount of cold working. It can be welded to chrome-molybdenum structure sufficiently well to take non-structural loads.

The question of how close a steel member may be to the compass without producing excessive disturbance is usually answered by the blanket rule of 24 inches. This is too rough a rule, for it implies that the thousand odd pounds of steel in the engine, located 25 inches from the compass is acceptable, while a single machine screw 23 inches from the compass is not acceptable. Actually, the strength of a pole induced by the earth's own field depends upon the mass of the member, its length, and its magnetic properties. Experience with chrome-molybdenum steel tubing has failed to show any instance where the induced field from a single tube exceeded a "strength of 1 inch," even up to sizes of $1^1/_2 \times 0.095$ inches, and 10 feet long, lying due north and south.

The author suggests a handy rule of thumb for the location of steel parts near the compass as follows: "The length of any steel object within 3 feet of the compass shall be at least 10 inches shorter than its nearest distance to the compass."

This rule will appeal to designers since it permits screws, nuts, and other small objects to be as close as 10 inches to the compass, while the larger objects are kept at a reasonable distance. It is more logical than the arbitrary 24-inch rule now in vogue. In fact, a detail study of the proposed rule shows that steel members may be magnetized up to a "strength of 3.5 inches," (which should never occur of any care is taken with the demagnetization if detail parts) without causing a compass error of over 1°. Magnetic strengths of this amount, if present, can be easily detected with a pocket compass, and their cause eliminated. The induced effects from the earth's field upon steel pieces of these lengths and at these distances is practically nil.

Book Reviews

Diesel Hand Book, by JULIUS ROSBLOOM; Diesel Engineering Institute, Jersey City, New Jersey, sixth edition, 1939; 719 pages.

This book appears to be a desirable reference work for Diesel operating engineers. It was written to supply the man of limited experience with the knowledge necessary for successful operation of the modern Diesel engines. The language is simple and easily understood. Lists of questions are provided after each section to test the reader's absorption of the text. In some cases the author, in an effort to clarify, has subdivided his statements too much, thus defeating his purpose. Chapters covering the "Theories and Principles" of the oil engine, "Fuels," "Metals," "Atomization Systems," "Engine Types," "Turbo Blowers," and "Marine Practice," represent only a portion of the work. In typical Diesel engineer fashion, the author refers to the Diesel as the "Aviation engine of the future," a statement which is at least open to some doubt.

FRANCIS J. WIEGAND
Wright Aeronautical Corporation

Elementi di Aerodinamica e di Dinamica del Volo, Volume II, by GIULIO C. COSTANZI; Editoriale Aeronautica, Rome, 1939; 344 pages.

This book, published in Italian, covers thoroughly the field of mathematical physics necessary for a complete understanding of aerodynamic theory, which is treated in detail and is the real object of this publication.

The first part covers dimensions, kinematics of fluids, and hydrodynamics. The second part is devoted to the principles and examples of Vectorial Calculus.

The Art of Soaring Flight, by WOLF HIRTH, translated from the German by NAOMI HERON-MAXWELL; Stuttgarter Vereinsbuchdruckerei A.G., Stuttgart, Germany, 1938; 190 pages.

In recent years the art of soaring flight has depended more and more on the utilization of thermal currents. The possibilities of this sport and the skill required have multiplied accordingly. The author of this book has purposely refrained from dwelling at length on the mechanics and meteorology of flight but has devoted many pages to experiences of his own and others. These are especially chosen to illustrate the principles of soaring flight.

Such important phases as storm riding, thermal soaring, cloud flying, and aerobatics are described fully. In addition there are excellent descriptions of soaring in Germany, England, and the United States. The experiences, in their own words, of some of the leading soaring pilots in the world will be of particular interest.

The book will stimulate a greater interest in soaring and gliding and give those who are familiar with the rudiments of the art just the advanced instruction they need to make better, longer, and higher flights.

The University of Washington's New 250 m.p.h. 8 × 12 Foot Wind Tunnel

FREDERICK K. KIRSTEN AND FRED S. EASTMAN

University of Washington

Introduction

DURING the early months of 1939, a thirteen month period of preliminary operation of the new wind tunnel at the University of Washington gave way to a steady program of tests. The preliminary period has demonstrated the practicability of several unusual features of this aeronautical laboratory, some of which add greatly to its operating efficiency.

Wind Tunnel and Power System

The tunnel building is a rectangular block 120 feet long, 65 feet wide, and 32 feet high. The tunnel proper is built of reinforced concrete throughout and constitutes the second story of the building, leaving ample space for office, computing rooms, research rooms, store room, battery room, and machine rooms on the ground floor. The tunnel is of Venturi closed throat, double return type, the flow chambers being arranged on a horizontal plane (see Fig. 1). The air stream is guided around the eight rectangular corners by deflector vanes which serve the double purpose of maintaining parallel flow throughout the air circuit and of cooling the air stream by virtue of the circulating water which they contain in their hollow structure. The breathing slot for the tunnel is located at the downstream end of the test chamber. Consequently, all other parts of the air circuit operate under more than atmospheric pressure.

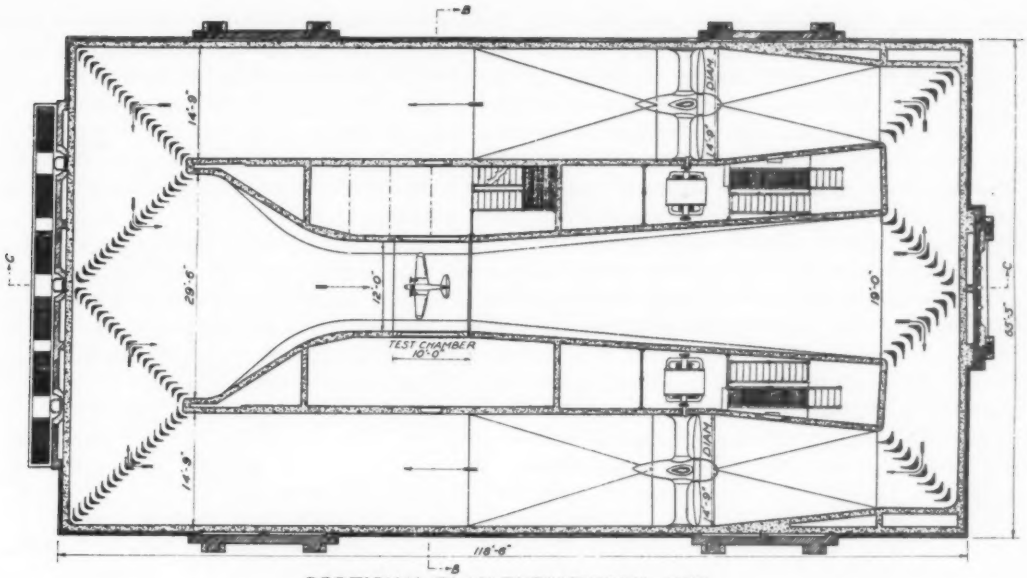
Two propellers are used, one in each of the two return ducts. Each propeller is driven by a 500 hp. direct current motor capable of delivering 750 hp. for one hour. These motors are mounted outside the air stream as shown in Fig. 1 and drive the propellers through spiral-bevel gears located in the housing back of the propellers. Thus the heat losses from the motors are kept out of the air stream and the housing is smaller than would be necessary to enclose the motor. A further advantage accrues to this design inasmuch as a second vertical motor can be added to the same gear train, driving the propeller through a second shaft leaving the housing through the vertical streamline support. Thus provisions have been made to double the horsepower input into the propellers, making it possible to increase the tunnel air speed to 320 m.p.h. in the future.

Power is delivered to the wind-tunnel building in alternating current form, but, to provide maximum selectivity of speed, it is changed to direct current by a motor generator set supplying variable voltage to the motors. The generator is designed to operate at the maximum voltage of 600, whereas the drive motors for the propellers are designed for 300 volts, the two motors being arranged to operate in series connection. This type of circuit guarantees that both motors carry exactly the same current under all conditions of operation, and by the proper adjustments of the field reostats of the two machines, the power output of the two at all speeds can be almost exactly equalized. To further guarantee the proper sharing of the load by the two motors, and in order to preclude the possibility of the hunting of the two parallel air circuits, the two motors are tied together mechanically through a belt driven counter shaft passing beneath the center chamber of the tunnel.

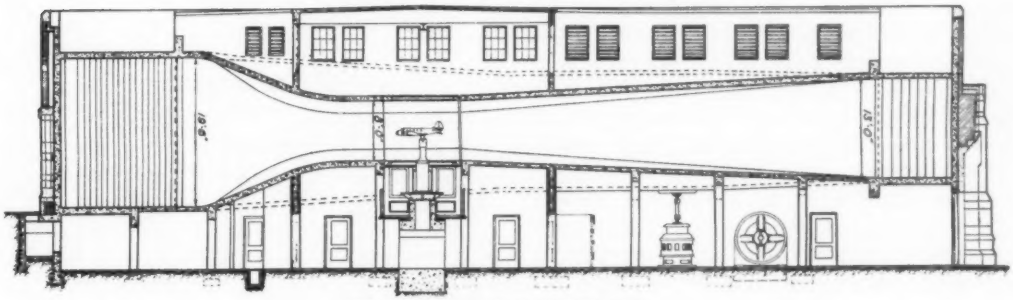
The two propellers are designed left and right handed in order to provide for symmetry of flow of both air circuits. Their position in the flow chamber was chosen so that with an assumed slip of 35 percent the pitch ratio would be in the range which yields maximum efficiency. The position of the propeller system, as shown on the drawing, has a further advantage of interposing between the model and the propellers two sets of deflector vanes which serve as protection for the propellers in case of the breaking of the model or in case of other accidents.

The propeller is seven bladed and has a diameter of fourteen feet nine inches. The odd number of blades was chosen because the number of housing supports had to be four to provide for the addition of a future vertical motor. Thus the housing strut interference with the slip stream of the blade only affects one blade at a time and results in a steadier flow with less noise and reduced severity of vibration. The disadvantage of such a setup is the fact that if one blade is damaged the whole propeller is out of action until the blade is replaced. With an even number of blades it is usually possible to carry on operations with one-half or one-quarter the number of blades of the full set. Since the propeller blades throughout their length from the base to the tip operate at low angles of attack, a high maximum lift coefficient is of no importance, and, therefore, a blade contour of symmetrical form was chosen so as to make use of its minimum drag characteristics. The pitch ratio varies from .8 at the tip to .9 at the hub in which the blade shanks are adjustably mounted for

Presented at the West Coast Annual Meeting, I.Ae.S., Pasadena, California, June 16, 1939.



SECTIONAL PLAN THRU TUNNEL AXIS



SECTIONAL ELEVATION "C"

FIG. 1a.

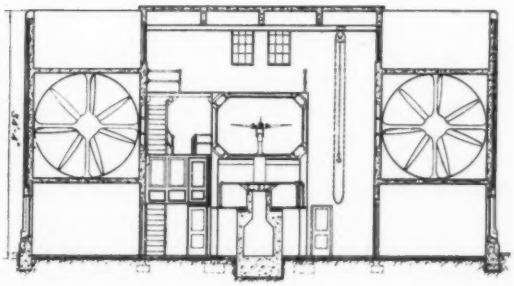


FIG. 1b.

pitch ratio changes. The blades are made of black walnut of specially selected stock and were carved and finished in the shops at the University of Washington.

The final choice of general design features was strongly influenced by the limited funds. Factors entering into the choice of the double return were the simplification of the form work, the double use of the same wind-channel forms, the smaller dimensions of the walls, and the saving residing in the duplication of design and size of deflector vanes and the accessibility of all parts of the tunnel chamber. The choice of the rectangular section in preference to circular section again is explained on the basis of minimum cost requirements.

OPERATING CHARACTERISTICS

The energy ratio based on power input to the motors was 6.5, based on a power reading of 970 kw. at 241 m.p.h., before the installation of a protective screen in front of the propellers. Measurements with the screen in place show a reduction to 6.2. This figure was obtained at 229 m.p.h., because of uncertainty regarding the strength of the trial screen installation. Using manufacturer's figures for motor efficiency, the corresponding energy ratios based on power input to the propellers are 6.95 and 6.65 . This high value may be attributed to the unusually long expansion tube before reaching the first set of vanes, and to the specially designed propellers.

Water cooling is often unnecessary during the winter months. A temperature rise of about 25°F. may be expected during a normal testing program at air speeds approaching 200 m.p.h., but higher speed and un-

usually long periods of operation may necessitate the use of water cooling regardless of outside temperature.

When first measured, the velocity distribution showed less than one half of one percent variation up to within two inches from the walls. This uniformity may have been caused by violent mixing of the air stream, because after adjusting the vanes to obtain minimum inclination of flow throughout the test section, velocity variations of about one percent were observed, the highest values occurring in the center of the channel. Additional adjustments are being carried on between tests, with a view toward further improving the airflow.

A thorough turbulence investigation has been postponed pending final adjustment of the air stream. However, the rather inadequate data already available indicates a turbulence factor, as defined in N.A.C.A. Technical Report No. 558, of 1.2 using an $8^1/_2$ inch sphere.

Model Suspension and Balance System

An important influence in the development of the special model mounting and weighing system was the desire to provide for rapid interchange of models so that two or more testing programs could be carried on alternately without serious loss of time resulting from the necessity of mounting and dismounting models. A major requirement was that it must be possible to rotate the model about a yawing as well as a pitching axis, and to simultaneously measure all six components of the air load, the dynamic pressure, and the angular position of the model about both axes. In addition it was desired that the system be able to record transient conditions such as the sudden changes which take place at stalling angles, and the changes in aerodynamic characteristics when the model is rotated rapidly.

The model is attached by means of a three pronged fork as seen in Fig. 2. The rear prong is forced up and down to adjust the angle of attack of the model which rotates about bearings at the top of the two front prongs. These bearings are normally imbedded in the wing of the model as shown in the photograph. Since friction in these bearings does not influence balance readings ball bearings are unnecessary, thus reducing the size of the mounting holes, which must be cut out of the model. The simplicity of this attachment enables one man to change models in a few minutes. The model can be detached from the fork, or the fork itself may be detached if a different one is to be used on the next model.

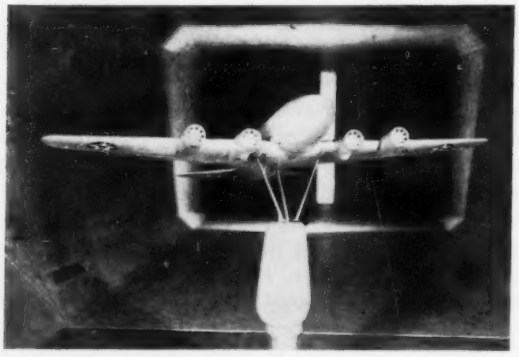


Fig. 2.

To provide rotation of the model about a yawing axis as well as a pitching axis, the two front prongs of the mounting fork are solidly attached to a hollow vertical shaft which extends down through the tunnel floor to a hydraulic control system shown schematically in Fig. 3. Oil under pressures up to 1000 lb. per sq.in. is used to actuate the pair of horizontal cylinders which turn the model in yaw, and the vertical cylinder which drives the rear prong of the fork causing the model to pitch. Two four-way valves are used to control the direction of the flow of oil to the cylinders. In their neutral position these valves stop the flow of oil so that the model is held fixed until the valves are open one way or the other. Speed of rotation of the model can be controlled between limits of about one-tenth of a degree per second to more than 30 degrees per second by means of speed control valves which control the rate of flow of oil from the cylinders.

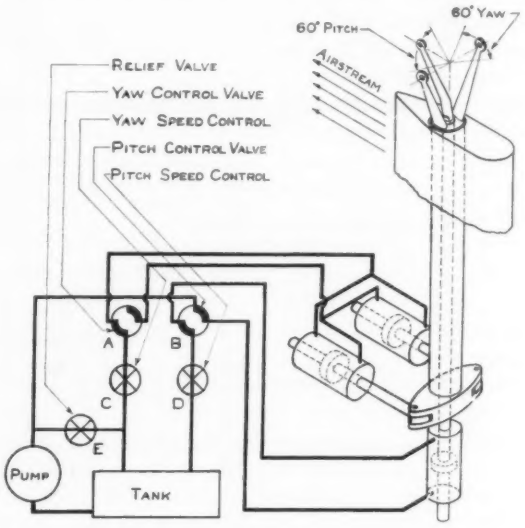


Fig. 3.

Except for the control valves and pump, the entire mechanism for turning the model is suspended on a system of flexure pivots* arranged to separate the six components of the air load. The pipes leading to the pitch and yaw control cylinders are arranged in such a way that they can transmit no noticeable reactions into the sensitive model suspension system. Fig. 4 is a

* Eastman, F. S., *The Design of Flexure Pivots*, Journal Aeronautical Sciences, Vol. 5, No. 1, pages 16–21, November, 1937.

diagramatic sketch showing how the six components of the air load are separated. The three moment components are transmitted from the model to the meas-

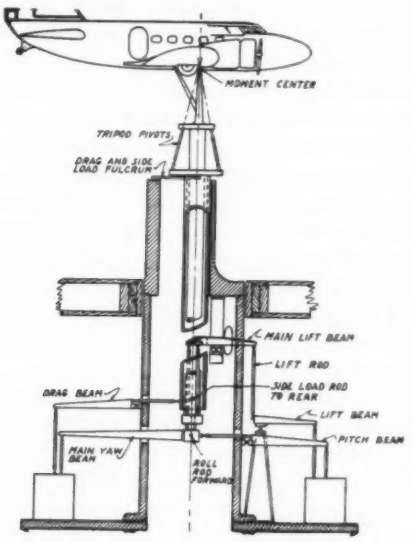


FIG. 4.

uring devices through the inside tube, which will be called the moment tube. The moment tube fits around the yaw control tube shown in Fig. 3, but does not turn with it. The tripod pivot near the top of the suspension system provides frictionless ball and socket action between the moment tube and the drag tube which surrounds it, leaving ample clearance for slight movement in any direction. If the drag tube is held fixed and the lower end of the moment tube is translated slightly in a horizontal plane, it will rotate about a point at the intersection of the prolonged axes of the three rods of the tripod pivot. This point will be called the moment center and is located at the intersection of the pitching and yawing axes. It will be seen that any tendency for the suspended system to rotate about the pitching axis will be counteracted by the pitch rod attached to the bottom of the moment tube. This rod has flexure pivots at its ends which enable it to resist a pitching moment but to yield readily to a rolling moment. Similarly the rolling moment is resisted by the roll rod which yields readily to a pitching moment. The yawing moment is resisted by a couple provided by the yaw rod and the roll rod. The lift force is also transmitted to the bottom of the moment tube where it is resisted by two vertical lift rods, one on each side of the moment tube. In this way the bottom of the moment tube is kept from moving forward by the moment rod; from moving sideways by the roll rod; from moving vertically by the lift rods; and from rotating by the yaw and roll rods. Each rod allows freedom in all directions except the one in which it is intended to act.

Drag and cross-wind forces applied at the moment center produce no tendency to rotate the moment tube, but they do tend to rotate the drag tube about its main fulcrum attached to the top of a streamlined cast-iron strut extending part way up into the test section. This fulcrum is a combination of flexure pivots which act like a universal joint preventing the drag tube from rotating about its own axis but allowing it to pivot freely about any axis lying in a horizontal plane passing through the main drag fulcrum. The fulcrum also provides freedom of movement in a vertical direction so that lift reaction cannot be applied by the drag tube instead of the moment tube. The drag rod and the cross-wind rod (marked side load rod in the sketch) react against the bottom of the drag tube, separating these components in the same manner in which the pitch and roll rods separate the pitching and rolling moments. Drag and cross-wind forces applied above and below the moment center introduce rolling and pitching moments which are separated by the roll and pitch rods as described above, but the reaction on the pitch rod adds to the load on the drag rod and the reaction on the roll rod adds to the load on the cross-wind rod. To prevent this interaction mechanically, it would have been necessary to further complicate the construction, resulting in reduced rigidity of the suspension system, and reduced natural period of the overall measuring system. A similar interaction occurs in the reaction on the roll rod because it is influenced by yawing moment. Compensation for these interactions is made automatically and instantaneously by means of special electromagnetic balances which measure the force required to balance each component of the air load.

The forces required to balance the suspension system are reduced by levers seen in Fig. 4, to suit the capacity of the measuring element which is from five to twelve pounds depending upon the amount of compensation required. This force is balanced by the electromagnetic force exerted on the actuating coil which is freely suspended in a powerful magnetic field, preferably maintained by permanent magnets of cast alnico, because the electromagnetic force is exactly proportional to the current flowing in the actuating coil as long as the magnetic field remains constant. The current in the actuating coil is automatically controlled by means of photoelectric cells P_1 and P_2 in Fig. 5, which keep the coil balanced between limiting positions less than .02 inch apart. A stock milliameter M, inserted in series with the actuating coil can be made to indicate the air load in pounds or any other units by merely adjusting the shunt resistances M_2 and M_4. Different resistances provide different ranges and sensitivities. For example, on its maximum range the lift meter reads up to 2500 lbs. with a precision of ± 25 lbs. or better, but by merely turning a switch any one of six other ranges is obtained, and the minimum range has one hundred times the sensitivity of the maximum range, reading up to 25 lbs. with a precision of $\pm$ .25 lb.

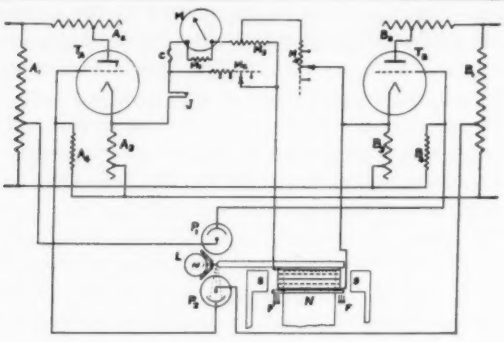


FIG. 5.

The current supplied to the actuating coils by the vacuum tubes T_A and T_B varies through the range ± 100 milliamperes, the magnitude depending upon the controlling photoelectric cells. Two separate power supplies provide 300 volts across resistances A_1 and B_1.

Compensation for the interaction between the several components, such as the influence of pitching moment on drag, is accomplished by passing the current from the pitch balance through a portion of the drag actuating coil. Shunts are used to adjust the compensation to the exact value needed.

Simultaneous readings of all six components, the dynamic pressure, angle of attack, angle of yaw, a clock with a second hand, wind-tunnel temperature, and barometric pressure are taken by photographing the instrument panel. A blackboard is mounted at the top of the panel so that the title of the test may be inserted and notes added with ease. A specially constructed camera is used to photograph directly on photostat paper giving pictures 5×8 in., which is large enough to permit easy reading with the naked eye. When necessary pictures can be ready to read within fifteen minutes from the time that they are taken from the camera.

As a supplement to the photographic method of taking readings, recording milliameters are mounted near the panel and can be plugged into the circuit of any of the balances when desired. This makes it possible to obtain immediate and continuous records of important readings, and to record peak values which may be missed by the usual point by point method. Since the electric measuring units respond to rapid changes of load, transient effects can be recorded.

Tests can be made very quickly with this equipment. A set of 15 readings is completed in from three to five minutes. When models are tested for yawing stability at several different angles of attack it is often possible to obtain four or five sets of readings in less than fifteen minutes because there is no appreciable delay in setting the model at any desired angle of pitch or yaw and it is unnecessary to stop the wind tunnel until all readings are taken.

In order to provide sufficient strength and rigidity the strut projecting up into the air stream was made five inches wide. In spite of the fact that the model is mounted nearly 12 inches above this strut, as shown in Fig. 2, experiments indicate that it has an appreciable influence on the air flow near the center of the model, but that placing a duplicate or image strut above the wing almost eliminates this effect. Also the form of the top of the strut has a pronounced influence and it is believed that further alteration of the form will eliminate the need for an image strut.

The drag of the mounting fork is less than 25 percent of the minimum drag of the airfoil used for preliminary check tests. This is an aid to obtaining accurate minimum drag readings. Moreover, the flexure pivots used throughout the suspension system eliminate friction and hysteresis effects, so that even unusually small forces, such as the resistance of the mounting forks alone, can be measured with the same consistency of readings as that obtained when measuring drag loads of 200 pounds.

Book Review

The British Aircraft Industry; The Society of British Aircraft Constructors, Ltd., London, 1939; about 400 pages.

The Society of British Aircraft Constructors has published a most comprehensive catalogue of the British aircraft industry. Authoritative data on aircraft, engines, and aircraft accessories, components, and materials are presented in English, French, and Spanish. This feature makes the volume especially valuable for the export trade.

Sir Kingsley Wood, Secretary of State for Air, says, in a foreword, "In spite of preoccupation with Royal Air Force contracts, I am glad to see that the British manufacturer is not forgetting the claims of export trade, and civil aviation will reap the benefit of the great work that is being done."

An examination of the directory by companies reveals that emphasis is given to products which are available for export, and listings of some of the newer types which are not in that class are omitted. The section of the book in which the accessories and materials are described is an excellent presentation of the wide coverage of British products.

The book should be carefully studied by the American aircraft industry; it is an example of cooperative effort which is certain to bring enquiries from all parts of the world. After the present extraordinary expansion of aircraft production in all countries is past, a highly competitive campaign for foreign markets is to be expected, and those countries which can best present their products will reap the greatest rewards. A similar directory of American products should receive careful consideration.

Notes on Recent Structural Research at Goodyear-Zeppelin Corporation

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Goodyear-Zeppelin Corporation

Stress Model Tests

THE use of models to predict the full-scale behavior of a structure is gaining increasing favor in the field of aeronautics. This trend to model investigation is due not only to the saving in expense, labor, and time involved, but also to a better understanding of model laws and to recent improvements in the art of properly representing the prototype structure.

Some time ago a practical type of model girder was developed, which permitted the axial, bending, and torsional elastic characteristics to be varied independently, and, further, it incorporated a convenient and sensitive means for measuring the corresponding strains and stresses.[1] As a part of an investigation program of the Special Committee on Airships a *complete* airship model, using this type of model member in place of the corresponding prototype girder, was constructed and tested.[2] The work was carried out with the financial assistance of the Navy Department. The test program was carefully chosen so that the effects of local loads could be conveniently isolated from the effects of general loads and in this way much of the confusion that has occurred in many previous model and full-scale tests was eliminated. Many variations of the structure were investigated such as with and without side or bottom gangway and with high and low initial tension in the shear wiring. Fig. 1 shows a part of the complete model rigged for test, with radial loads being applied to springs between the model and external loading rings.

Presented in abstract form as a part of the Lighter-than-Air Symposium, Seventh Annual Meeting, I.Ae.S., January 26, 1939.

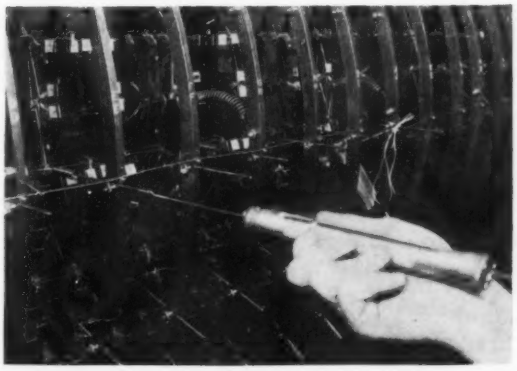

FIG. 1. Close up of model and loading arrangement.

The results obtained from tests on this model formed an excellent basis for evaluating existing methods of stress calculation of airships[3] and have answered many questions concerning various features of design. For example, the distribution of stress resulting from general bending and shear was fully investigated with regard to the effect of initial tension in the shear wiring. It was found that, if the initial tension exceeds a certain amount, the stress in the longitudinal girders follows the conventional cos ϕ distribution around the circumference or a straight line distribution as expressed by the beam formula, and the shear forces in the wires follow the sin ϕ law. If, however, the wires become slack under loading, the stress distribution is disturbed, particularly if the slackness of the wires is appreciable, and this disturbance follows certain definite laws.

The "Principle of Superposition," which has been the subject of considerable speculation, was checked by (1) testing the model under separate side and end loads, and (2) by testing with combinations of these loads. It was found that, for most cases of loading within the design working load limit, the errors introduced by superimposing the individual loading results were not important.

The local effects of concentrated circumferential loads was found to be confined in the longitudinal direction to one or two intermediate frame spacings only, and the local effect of a concentrated radial load was limited principally to the adjacent main bay and main frame.

Other isolated structural parts of an airship, such as a single transverse frame with bulkhead, empennage structure, etc., were represented by models using the same basic principles and tested under loading conditions likely to occur in the prototype. It is interesting to know that in models of structures for which precise theories exist, the test values resulting from design loading conditions checked the theoretical calculation within 3 percent of the ultimate strength of the prototype member.

Stability Models

The problem of general structural instability of airships hulls, like stiffened cylinders, has been given considerable attention. This problem has not been so critical in the past because the structural members of which the built-up structure was composed had a relatively low static or local strength. However, the

advent of higher local strength members and larger structural radii enhances the importance of this problem and a rational method, capable of safe and efficient extrapolation, is required.

In 1934 the Goodyear-Zeppelin staff developed an analytical treatment of this problem; test results obtained with rather crude models enabled a rough check of the theory. Recently, and as a further part of the model contract for the Navy Department, a series of tests on several elaborate structural stability models of an airship main bay has been completed. These models, cylindrical in shape and consisting of longitudinal members and transverse frames diagonally braced by a great number of shear wires, as shown in Fig. 2, were designed to represent a conventional airship main bay, except that the local and Euler strengths of the longitudinal members were made high to insure failure by general instability instead of local stress.

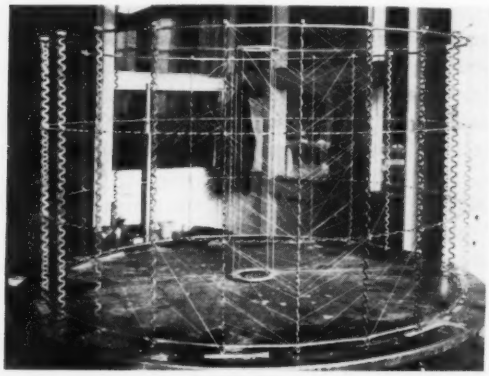

FIG. 2. Stability model of an airship main bay.

The type of model member used in these tests differed from that used in the stress model investigation, but it likewise permitted variation of the axial, bending, and torsional characteristics independently. A great deal of care was exercised in their design and construction in order to insure uniformity of model members, joints, dimensions, etc.

In this investigation the effects of various types and arrangements of shear wiring, of initial tension in the shear wiring, and of internal pressure on the stability strength of the represented structure, were studied.

A survey of the test results indicates that the stability strength of a conventional airship structure such as that used as prototype for this test is higher than the designed local strength, and that initial tension in the shear wires and internal pressure have favorable effects.

The variations in the test results of all models were remarkably consistent with predictions on the basis of the aforementioned theory and thus indicate that the stability strength of such a structure can be treated analytically with a good degree of accuracy.

It would seem reasonable to suppose that the same type of treatment may be applicable in determining the stability strength of stiffened shell construction.

STRESS CHANGE RECORDER

Another development carried out recently for the Navy Department is a "stress change recorder." This instrument is for the purpose of recording the maximum stresses as well as the total number of stress changes of a number of different magnitudes experienced by an aircraft member during its flight history.

This instrument, weighing only a few ounces, appears to be valuable for collecting data to permit an appraisal of the fatigue resistance to be desired in a particular member and also to give an indication of the frequency and magnitude of the varying loads on the structure as a whole.

A simple method of interpreting data recorded over a relatively short period has also been developed which should give a reasonable indication of the fatigue life to be expected for that member.

The instrument, as shown in Fig. 3, makes use of ratchet wheels requiring a definite amount of motion—or stress change—to be operated. The ratchet wheels

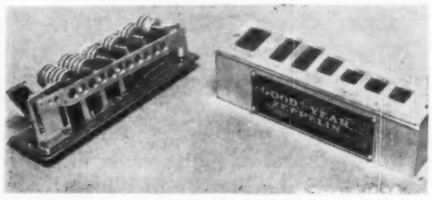

FIG. 3. The stress change recorder.

are connected with counting devices which record the number of stress changes for each range of stress.

At present this recorder is installed on a fin brace cable of a non-rigid airship. Fig. 4 shows data collected by the instrument.

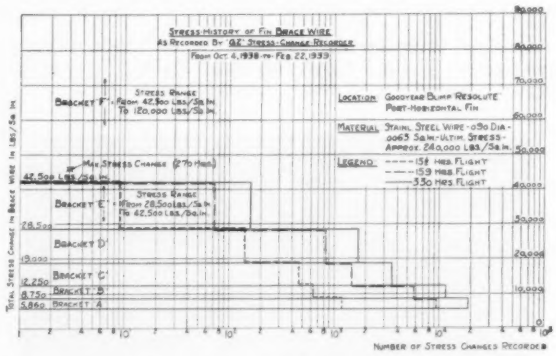

FIG. 4. Stress change history of fin brace wire on a non-rigid airship during flight.

FATIGUE TESTS ON GIRDERS AND BOOMS

In addition to previous axial tension and compression tests on aircraft girders[4] conducted in a high frequency fatigue testing machine,[5] some fatigue tests on alumi-

num alloy tubes and girder booms including various stress raisers such as open holes, rivets, welds, and gusseted types of connections have recently been carried out.

The tests show that some difference exists between open and rivet-filled holes, likewise between welds and rivets and ordinary surface imperfections and possibly between the various materials used in the manufacture of high strength members. However, these differences appear to be small and for practical purposes it can generally be said that the fatigue strength of these structural members including imperfections of the nature mentioned above are substantially the same. This is particularly significant since the flexural fatigue test results for the Alclad material without imperfections is appreciably lower than the corresponding plain material without the soft coating. This conclusion is supported by the test results shown in Fig. 5.

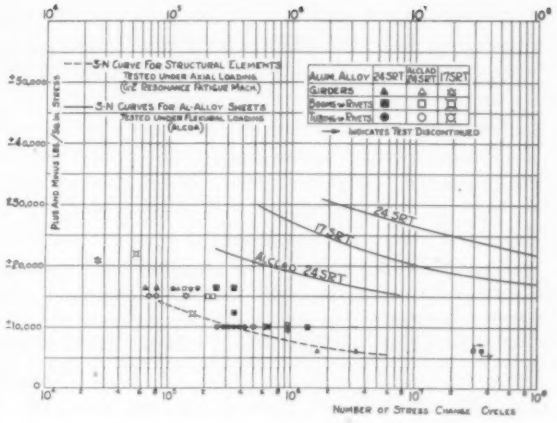
S-N CURVE FOR STRUCTURAL ELEMENTS TESTED UNDER AXIAL LOADING (G-E RESONANCE FATIGUE MACH.)
S-N CURVES FOR AL-ALLOY SHEETS TESTED UNDER FLEXURAL LOADING (ALCOA)
ALUM. ALLOY 24 SRT
ALCLAD 24 SRT
17 SRT
GIRDERS
BOOMS OR RIVETS
WELDS OR RIVETS
INDICATES TEST DISCONTINUED
24 SRT
17 SRT
ALCLAD 24 SRT
NUMBER OF STRESS CHANGE CYCLES

FIG. 5. Results of fatigue tests on gusseted aluminum alloy structural elements.

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[3] Arnstein, K., and Shaw, E. L., *Methods of Calculating Stresses in the Hulls of Rigid Airships*, Proceedings of the Fifth International Congress of Applied Mechanics, Cambridge, Massachusetts, September, 1938.

[4] The Goodyear-Zeppelin Corporation, N.A.C.A. Technical Note No. 637.

[5] Hudson, R. A., and Chick, J. E., *Acceleration of Fatigue Tests*, Aero Digest, September, 1937.

Book Reviews

Handbook of Aeronautical Vocations, by WALTER VAN HAITSMA; Zeeland Record Company, Zeeland, Michigan, 1939; 47 pages.

The recent expansion program of the aeronautical industry in this country foreshadows a wide appeal for this booklet. It is "a vocational guide for careers in all phases of aviation."

All of the necessary information on duties, professional and personal qualifications, and promotional stages are given clearly and concisely. It is divided into six parts: "Aviation as a Career," "Explanatory Notes on Vocational Chart," "Vocational Charts," "Choosing the School," "Helpful Suggestions," and "Selected Reading Material."

Mr. Van Haitsma, a vocational lecturer and counselor and formerly Director of Placement for the Training Division of United Air Lines, has a background of experience which enables him to speak authoritatively on the subject.

The book not only contains a great deal of information for the young person who is considering a career in aviation but will be welcomed as well by those who are asked for advice on how to enter the aeronautical field.

Fighting Planes of the World and **Aircraft of the World, Recognition Book,** edited by E. C. TALBOT-BOOTH, compiled by ERIC SARGENT; D. Appleton-Century Company, Inc., New York and London, 1938; 601 pages and 1044 pages.

These books supplement each other. One limits its scope to military aircraft of the world and descriptive chapters on the Royal Air Force, its history, functions, and equipment. The other, as its title implies, gives the information necessary to identify the aircraft of the world, supplementing the "recognition drawings" with condensed performance data wherever possible.

The unique feature of each book is its handy size. Condensed into 600 pages, the volume on fighting aircraft devotes two facing pages to each type described. A good photograph is supplemented by an identifying name, the type, the manufacturer, the dimensions, weights, performance, and any additional information which may be helpful. A third of the pages are used to give as complete information regarding the R.A.F. as can be found in any reference work.

The Recognition Book, in its thousand pages, renders a service that is usually available only in confidential charts that all air forces have for the guidance of pilot officers. Three-view silhouettes give the proportions of each type. As in the volume on fighting airplanes, data on performance, weights, etc., supplement the drawings. The first part of the book describes commercial aircraft and the second treats the leading military and naval aircraft of the world.

Many omissions, due to obvious restrictions, will be noted, but the authors merit great credit for such painstaking research and interpretation as was necessary to make the publication of these books possible. They are indispensible guides to the identification of the ever-increasing range of types of modern aircraft. The widespread demand they deserve should encourage the editor to publish supplementary volumes from time to time.

The Grant Streamline Flap

WILLIS L. NYE

Aviation Press

ABSTRACT

This paper describes a new type of airfoil flap which presents possibilities of obtaining higher lift coefficients when used with conventional airfoils. The wind-tunnel investigation was performed at New York University and the results of this investigation are discussed. The results show that a substantial increment in the lift performance of conventional airfoils is possible provided the flap functions did not disrupt the boundary layer airflow. It was established that radical variations of the position of the center of pressure did not follow on the N.A.C.A. 23012 airfoil which was equipped with this flap when the flap was deflected. While the movement of this flap involves mechanical linkages, little increase in the parasitic resistance was found.

UNDER the existing Civil Aeronautics Authority regulations, the landing speed of commercial aircraft cannot exceed 65 miles per hour, and in order to comply, it is compulsory that wing flaps be employed if a high performance is to be attained. Except where a sliding projected type flap is used, the conventional flap in its many forms is practically useless in assisting the take-off as well as landing operation, mainly because the generation of drag is high in proportion to the gain in lift. The solution of this problem resolves itself into the employment of a flap which generates high lift with a minimum of drag. This is the specific function of the Grant Streamline Flap[1] and prompted the original development.

DESCRIPTION AND TESTS

The profile of a normal airfoil equipped with the Grant flap is shown in Fig. 1. It is apparent that the

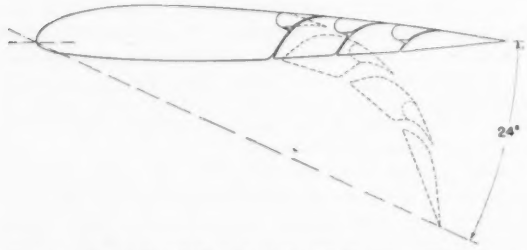

FIG. 1. Normal airfoil equipped with Grant multiple flaps.

cross-section profile is not altered abruptly when the flap is deflected and that the boundary layer airflow is maintained by the airflow through the slots. The flap operation is accomplished by mechanical linkages and is adaptable to any conventional airfoil with a stable Center of Pressure.

Received February 24, 1939.

In Fig. 2 are shown the results of wind-tunnel tests with various slot settings and deflections of the trailing edge. The tests were conducted with a four segment flap on an N.A.C.A. 23012 airfoil. The various configurations are shown in Fig. 3. A lift coefficient of 2.6 at an effec-

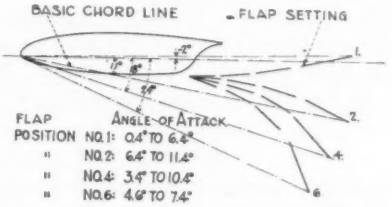

FIG. 3. Configurations used for test results shown in Fig. 2.

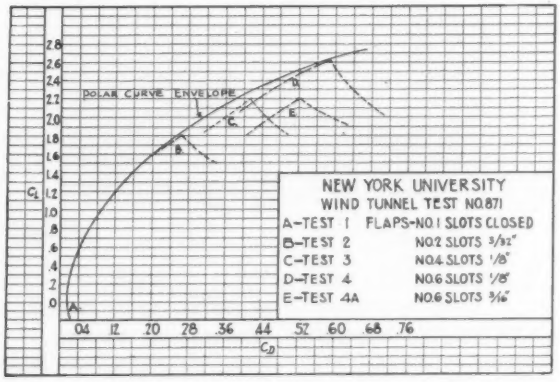

FIG. 2. Polars of N.A.C.A. 23012 airfoil equipped with 4 segment Grant flaps.

tive Reynolds Number of 389,000 is obtained with an airfoil of moderate thickness. During the tests, the operating mechanism for the flaps was mounted on the lower surface of the airfoil model and even with these excrescences, the drag was quite low.

The normal lift coefficient for this size model and wing section reaches a maximum value of 1, but with this identical model equipped with the flap of Fig. 1 a maximum lift coefficient of 2.6 was developed.

Fig. 2 shows the effect of variation in the upper surface slot opening on lift and drag in the No. 6 position, indicating that the area of the slot opening is very important. The polar curve of the test with No. 4 flaps falls below the polar curve envelop shown in Fig. 2. This is due in all probability to the use of a slot opening which was not the optimum for that flap deflection. The test described here in its entirety was run at a Reynolds Number of 278,000 but the correction for

wind-tunnel turbulence gives an effective value of 389,000.

The final estimations of $C_{L_{max.}}$ for the Grant flap at Reynolds Numbers of 10, 15, and 20 millions were 3.185, 3.270, and 3.335, respectively. These values were obtained by extrapolating the test data of the N.A.C.A. 23012 airfoil to the desired Reynolds Number and then adding these figures to the $C_{L_{max.}}$ shown by the tests with the flaps depressed. This correction is based on a series of tests with the N.A.C.A. 23012 airfoil with an external flap.[2] This airfoil and external flap approximates the principle of the Grant slotted flap airfoil.

The minimum drag in this instance is 0.012. When a thicker airfoil is employed, a substantial increment in maximum lift is possible, though at a corresponding increase in the minimum drag.

A variation of the median line alters the position of the Center of Pressure, and the wing weight is largely predicated upon the magnitude of the Center of Pressure variation. The Center of Pressure movement when this flap is employed is similar to that of a normal airfoil with a hinged flap of one segment.

The model had slotted and adjustable flaps, the adjustment ranging from −2° to 24°. Slot openings on the upper surface of the airfoil were varied by altering the curvature of aluminum strips which covered the flap segments. Slot apertures on the lower surface of the airfoil automatically adjusted themselves with any change in flap deflection.

The tests were conducted in a nine foot wind tunnel at an airspeed of 59.4 m.p.h., referred to standard air. The angles of attack were taken from the chord line of the fixed portion of the airfoil. The term chord line angle is defined as the angle between the chord line of the fixed portion and the chord line made by joining the leading and trailing edges of the wing with flaps deflected (see Fig. 3).

The data for test 4 (Fig. 2) are given here This test was used to compute the Center of Pressure movement and the moments about quarter chord point. The flaps were adjusted to No. 6 position (Fig. 3) with the slots open $^1/_8$ inch and the chord line angle was 24° (Table 1).

Operation of the Flap

The increase in lift with a conventional flap is approximately proportional to the degree of deflection below its normal raised position, up to a certain well defined point. At this point separation takes place, the lift decreases and the drag increases. This separation definitely limits the flap size and the degree of deflection.

In Fig. 4a, the slot is disposed between the leading edge of the flap and the rigid portion of the wing. When the flap is deflected, air passes up through the slot and ejects out along the upper surface of the wing as in Fig. 4b. This jet of air allows the flap to be deflected further than the slotless flap, before separation occurs. To attain greater deflection without greater angular deflection, the flap chord can be made larger.

The Grant flap permits the edge of the flap to be depressed to more than 38 percent of the chord below the chord line of the original airfoil. Fig. 4c shows the flap of two segments in normal attitude. Fig. 4d shows the flap fully depressed to a high lift position.

The limitation of deflection and size makes it evident that the single flap retards boundary layer separation only to a limited degree of deflection. However, if two slots are employed and two segments form the flap, both of which may be depressed, it is evident that the two slot flap may be wider than the single flap, and that the deflection may be much greater, with a consequent increase in the lift. In Fig. 4d the deflection of the inner segment is less than the angle of maximum deflection of the single flap. The airflow over this latter flap is sustained up to an angle of 40°. The airflow over the inner segment of the two segment flap remains smooth, since its deflection is only about 30°.

It is feasible to use this flap with multiple segments. However, for reasons of simplicity, the two segment

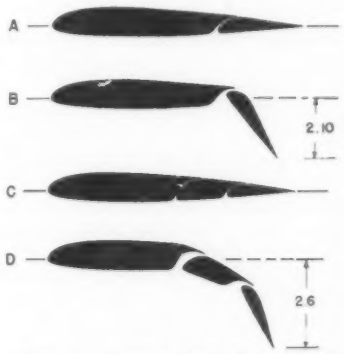

Fig. 4. A comparison of a normal single flap airfoil and the Grant two flap airfoil.

Table 1

Center of Pressure Movement

Angle of Attack	C.P. in Percent of Chord	$C_{M_{c.g.}}$
−4.6	55.6	−.530
−2.6	52.5	−.577
−1.6	51.7	−.594
−0.6	51.2	−.604
0.4	50.9	−.611
1.4	50.4	−.614
2.4	49.7	−.610
3.4	48.6	−.600
4.4	47.6	−.587
5.4	47.0	−.572
6.4	46.0	−.556
7.4	50.2	−.525

flap will be the most practical, while retaining the capacity to generate lift far in excess of conventional wings. In this instance, the slots at their intake end are nearly twice as large as in the case of the multiple segment wing, but the outlet openings are similar in discharge area. Hence, a greater volume of air at a higher speed is discharged from the slot openings of the two segment flap than those of the multiple segment flap. Tests by Piatelli[3] indicate that adequate scavenging is obtained with a two segment flap provided the slots are properly designed.

The tests described show the possibility of obtaining a maximum lift coefficient of 2.6 with a minimum drag coefficient of 0.012 by the use of this flap, thus permitting a large difference between landing speed and high speed. The author is not aware of any other flap device which has a minimum drag coefficient as low as 0.012 in conjunction with a maximum lift coefficient as high as 2.6.

Normal flap action impairs aileron control at stalling speed but this problem has been solved here in an original manner. The semi-span of the wing contains two inner flaps which can be depressed up to 24°. Two outer flaps act as ailerons but these are only depressed half as much as the inner flaps. The aileron flaps function normally without any impairment of the lateral control, mainly because the airflow over the aileron flaps, by virtue of the slots in front of the aileron, remains smooth when the flaps are deflected.

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[2] Platt, Robert C., and Abbott, Ira H., *Aerodynamic Characteristics of N.A.C.A. 23012 and 23021 Airfoils with 20-Percent-Chord External-Airfoil Flaps of N.A.C.A. 23012 Section*, N.A.C.A. Technical Report No. 573, 1936.

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Book Reviews

Arc Welding in Design, Manufacture, and Construction; The James F. Lincoln Foundation, Cleveland, Ohio, 1938; 1402 pages, $1.50 in U.S., $2.00 elsewhere.

This volume comprises a selected list of 109 of the 1981 papers submitted to The James F. Lincoln Arc Welding Foundation for its recent Award Program. They cover a wide range of applications of arc welding to modern fabrication problems.

The aeronautical section, covering 59 pages, comprises six papers. The first, by L. J. Carey and Marvin Whitlock on "Arc Welding in Aircraft Heating" describes the savings effected by arc welding the boilers of aircraft steam heating systems. "Arc Welding in Aircraft" by Ralph H. Upson advances a type of construction and method of design which will permit arc welding and its inherent economy in modern all-metal aircraft. "Arc Welding for Economy in Constructon of Beaching Gears for Large Planes" by James W. Fitch and John Czarniecki, Jr., describes the beaching gear for the Boeing Clipper and states that a saving of 31.7 percent was accomplished by the use of arc welding in its fabrication. "Arc Welded Aeroplane Landing Gear Fork and Tests of Aircraft Welds" by C. R. De Laubenfels describes the saving and increased service life of arc welded landing gear forks. "Design of an Outer Wing Panel for Large Airplanes" by W. E. Savage and J. B. Johnson describes this design, which employs a single spar fabricated from heat treated alloy steel, arc welded, to take the bending and shear loads, and a nose section of stainless steel, spot welded, to absorb the torsional loads on the wing. "The Potentialities of Arc Welding in Airplane Design" by Ray P. Holland, Jr., describes many of the parts of the modern airplane where arc welding might allow great savings in fabrication costs.

Airports, 1939; The Airport Directory Company, Hackensack, N.J., 1939; 320 pages, $2.00 in U.S., $3.00 elsewhere.

The 1939 edition of this reference handbook is, as the other editions have been, an invaluable aid to pilots who engage in cross country flying. Instead of drawings, which are sometimes difficult to decipher and may be confusing, there is an aerial photograph of each airport.

In addition, the essential information regarding the principal airways and radio stations is given.

The Law of Aviation, by HENRY G. HOTCHKISS; Baker Voorhis and Company, New York, second edition, 1938; 598 pages.

Ten years ago Mr. Hotchkiss, a member of the New York Bar, published the first edition of this book on the legal aspects of aviation. Since then there has been a development in this field as marked and as rapid as that in the art of flying. International, national, state, and municipal laws and regulations have created new boundaries which have given way to controlling decisions substantially settling the principal questions that were unsolved, or dubious when the first edition of the book was published.

This comprehensive study of the present status of Air Law gives the limitations marked by statutes, treaties, or decisions, and points to questions still to be answered. The presentation of all phases of the law of aviation is commendably brief for a book of such wide scope. It is well documented, so that those interested may easily find further and more specialized information.

The appendices will prove an invaluable source of reference material. They reprint the texts of the leading International Conventions, the various U.S. civil air regulations, the present and proposed Uniform State Law and Aeronautics Code and the Great Britain Air Navigation Act of 1936.

As a standard work the book is unexcelled and will be of inestimable value to those charged with the solution of air law problems.

Un Diccionario de Aeronautica, by C. T. REID; Aviation Press, San Francisco, 1939; about 125 pages, $3.00 (lithographed).

With our export business to South American countries growing so rapidly, a Spanish-English dictionary will be a most useful handbook for those whose duty it is to deal with our S.A. friends who speak only Spanish. Even though one speaks a language fluently he frequently has difficulty with the correct translation of technical terms. Mr. Reid has spent many years making the compilation for his own use. Friends urged him to make his notes available to others, and the present dictionary is the result. English-Spanish and Spanish-English sections make the dictionary complete for both languages.

Empirical Formulas for Allowable Compression Loads in Stiffened Sheet Panels

E. ROBERT REFF

Bellanca Aircraft Corporation

ABSTRACT

The author presents a general formula for the strength of any flat sheet-stiffener combination, the necessary empirical constants being given for a limited range of extruded stiffener shapes. It is suggested that this formula may be utilized in laying out test schedules for other stiffener shapes for which such constants are not now available. Existing test results, if sufficiently broad in scope, may be used to determine the empirical constants for stiffener shapes other than those considered. The number of tests necessary to obtain design data for a given range of stiffener shapes and sizes may be greatly reduced by use of the formula, and determining the necessary empirical constants, rather than running a complete schedule of exhaustive tests, will expedite stress analysis procedure. It is recommended that further tests be run to correlate the effects of rivet spacing.

INTRODUCTION

SECHLER,[1] von Kármán, Cox, Marguerre, and others[2] have derived approximate formulas for the effective width of sheet acting with each stiffener at the same stress as the stiffener, which may be used to calculate allowable design loads. However, the use of these formulas involves questionable assumptions as to the buckling stresses developed in the sheet midway between stiffeners, which vary widely depending on the type of support afforded the sheet by the stiffeners.[3] In spite of the popularity of the effective-width method of sheet-stiffener design where specific test data are lacking, considerable caution must be exercised in its application. Available formulas are based mainly on the behavior of the sheet prior to buckling beyond the elastic limit. However, the ultimate strength after elastic buckling has been exceeded is usually the major factor in designing monocoque structure, depending on the specified ratio of yield to ultimate loads. The formula developed by the author is concerned only with ultimate loads. After elastic buckling has been exceeded, a redistribution of stresses occurs in the sheet beyond which classical buckling theory is no longer strictly applicable. The formation of wrinkles in the sheet may invite premature stiffener failure, and conditions existing at or near ultimate failure are very difficult to analyze. The author's formula divides the load carried by any combination of sheet and stiffener into its two fundamental components and a means of separating the load carried by the sheet from that carried by the stiffener has been devised to establish the parameter R, a measure of the overall efficiency of the sheet in carrying load. It is significant that R incorporates the combined effects of effective width and variation in stiffener stress.

Empirical constants of the general formula are determined from test data for flat aluminum alloy sheet attached to various stiffener shapes. No data pertaining to the effects of curvature of the sheet were available. However, from the viewpoint of ultimate loads, it is believed that the increase in strength due to curvature of the sheet is nearly all lost after buckling occurs, since the buckling of the panel tends to flatten it locally.

Received May 27, 1939.

The author is indebted to Roy A. Miller of the Consolidated Aircraft Corporation for cooperation in making possible the analysis of the vast amount of test data forming the basis of the work presented here, and to the Bureau of Aeronautics, U.S. Navy, for permission to publish the same.

ANALYSIS

The following symbols are used:

- b = width of sheet attached to each stiffener (stiffener spacing)
- t = thickness of sheet attached to stiffener
- A_0 = area of stiffener section
- A = $A_0 + bt$ = area of one stiffener and its attached width of sheet
- F_{c_a} = P/A = average stress in sheet and stiffener
- P = $F_{c_a}(A_0 + bt)$ = load in pounds carried by one stiffener and its attached width of sheet
- P_0 = Value of P for $t = 0$ (as determined by straight-line extrapolation of the load curve)
- F_{c_0} = P_0/A_0 = hypothetical stiffener stress for $t = 0$
- L = column length of sheet and stiffener (bulkhead spacing)
- ρ_0 = radius of gyration of stiffener section about its neutral axis parallel to the plane of the attached sheet
- c = end-fixity coefficient of stiffeners at bulkheads
- d = rivet spacing parallel to direction of loading
- c' = end-fixity coefficient of sheet between rivets.

The fundamental substance of this paper is that the load in pounds carried by any combination of sheet and stiffener plotted against t as the only variable may be represented in rectangular coordinates as a straight line with a positive slope. A great number of test data bear out the validity of this relation within the limits of experimental accuracy for sheet gages between $t = .020$ and .125. It is strongly suspected that for sheet gages below about .020, this assertion is conservative, and that the curve actually flattens out at its lower extremity. However, for reasons which will later become

obvious, granting that the load curve does actually flatten out for small sheet gages, it is nevertheless necessary to use the intercept of the straight line portion of the load curve extrapolated to $t = 0$ in developing a load formula.

Fig. 1 shows that the slope of the load curve is a function of b, and that a series of load curves representing different values of b will converge at $t = 0$ to a value of $P = P_0$. Furthermore, it is found that if b is held

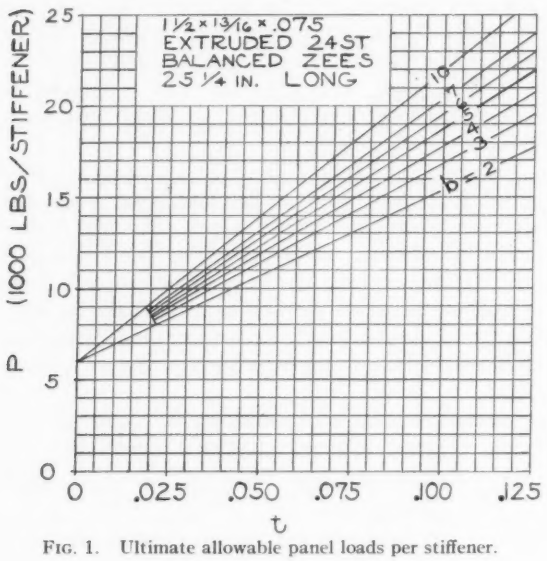

FIG. 1. Ultimate allowable panel loads per stiffener.

constant and L varied, the load curves are parallel with different values of P_0 for each value of L.

The designing engineer is primarily interested in the average stress carried by any sheet-stiffener combination for purposes of weight comparison. As long as the flexure formula $f_b = My/I$ is used to obtain the applied stresses in wing panels, the allowables must be average stresses in order that both will be based on total area of sheet and stiffeners, as is generally used in computing section properties of the wing. If A is plotted against t for various values of b, a family of straight lines will be obtained which also converge at $t = 0$ for some value of $A = A_0$. Hence, it is obvious that the ratio $\Delta P/\Delta A$ is a constant for any given value of b, where $\Delta P/t$ is the slope of the load curve and $\Delta A/t = b$ is the slope of the area curve.

The average stress function R will now be defined as

$$R = P/A = (P - P_0)/bt \qquad (1)$$

which is a measure of the effectiveness of the sheet in carrying load.

Fig. 2 shows results from tests of three typical stiffener sections in which R is plotted against $1/b$. From these and other tests, it was found that the expression

$$R = K(1/b)^n \qquad (2)$$

fits the experimental points reasonably well. A mean value of $n = {}^2/_3$ has been found to fit all available test data within the limits of experimental accuracy, regardless of the size or shape of the stiffener considered, for both $17ST$ and $24ST$ materials.

From Eqs. (1) and (2),

$$P = P_0 + Kb^{1/3}t \qquad (3)$$

The physical significance of this formula is simply that the total load carried by any sheet-stiffener combination consists of the load carried by the stiffener plus the load carried by the sheet, in which P_0 is the former and $Kb^{1/3}t$ is the latter. It is pointed out that since P_0 is in all probability a hypothetical load, it is to be expected that it will not check with actual loads as obtained from column tests of stiffeners restrained against twisting but with no sheet attached. However, the error involved in a low value of P_0 is slightly conservative for small sheet gages, and diminishes to zero with an increase of sheet thickness to about $t = .020$, which is a practical minimum from a design standpoint.

DETERMINATION OF K

Values of K have been determined for several standard sizes of balanced and unbalanced zee stiffeners, and flat-topped hat stiffeners (Fig. 3). With the exception of one $17ST$ balanced zee section, all of the sections are of $24ST$ material and only extruded shapes are considered. Values of K for each extrusion appear in Table 1. In cases where sufficient geometric similitude exists to warrant interpolating for the K of a stiffener size in between two known values, the following formulas may be used: (For $24ST$—ultimate loads, 1 in. rivet spacing)

$$\text{Balanced zees:} \quad K = 125{,}000\, A_0^{1/3} \qquad (4)$$

$$\text{Unbalanced zees:} \quad K = 131{,}000\, A_0^{1/3} \qquad (5)$$

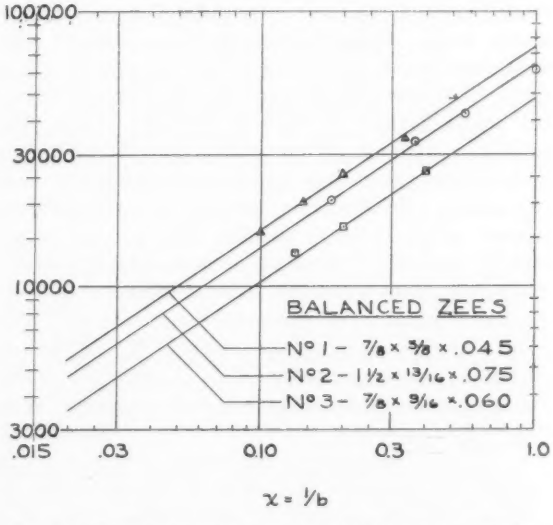

FIG. 2. Graphical solution of $R = K(1/b)^n$ for three typical stiffener sections.

TABLE 1

Properties and Constants of Standard Extruded Stiffener Sections

Section Ref. No.	Alcoa Die No.	Description: Material	Shape	Size	Properties: A_0, In.^{2}	Properties: ρ_0, In.	Constants*: $K/1000$	Constants*: $k/1000$
1	K14040	24ST	Bal. Zee	$^7/_8 \times {}^5/_8 \times .045$	.1000	.3564	48.5	42.0
2	K8669	24ST	"	$1^1/_2 \times {}^{13}/_{16} \times .075$	.226	.5827	75.0	"
3	K775	17ST	"	$^7/_8 \times {}^9/_{16} \times .060$	.1189	.3441	64.5	....
4	K9047	24ST	"	$1 \times {}^{11}/_{16} \times .050$	.134	.4043	64.5	42.0
5	K14034	"	Unbal. Zee	$1^1/_2 \times .070$ Vertical	.226	.585	80.0	37.8
6	K13685	"	"	$1 \times .050$ "	.130	.404	65.5	"
7	K14035	"	"	$1^1/_2 \times .079$ "	.291	.567	87.0	"
8	K13672	"	"	$1^1/_8 \times .065$ "	.174	.433	74.0	"
9	K14219	"	Hat	$1^1/_2 \times 3^{11}/_{16} \times .078$	.4395	.557	132.0	47.0
10	K14073	"	"	$1^1/_2 \times 3^{11}/_{16} \times .089$	.4839	.553	129.0	49.0
11	K14074	"	"	$1^1/_2 \times 3^7/_8 \times .117$	.6821	.561	160.0	45.0
12	K14075	"	"	$1^1/_2 \times 3^7/_8 \times .135$	.7591	.5375	145.0	57.0

* Values of constants are for ultimate allowable loads and for 1 in. spacing of rivets through sheet as follows:

Zees: Single row of $^1/_8$ in. dia. Brazier head rivets.

Hats: One row of $^5/_{32}$ in. dia. Brazier head rivets in each leg.

Eq. (5) gives close agreement with the values of Table 1 throughout the entire range of stiffener areas considered, but Eq. (4) checks only the two larger of the three 24ST balanced zee sections. It is recommended that whenever possible, actual values of K be determined from test data (as in Table 1), Eqs. (4) and (5) being used for interpolation only when the dimensions of the stiffener sections are proportional. Extrapolation for K by means of Eqs. (4) and (5) is not advisable except for small increases in stiffener area.

Values of P have been obtained by dividing the total panel test load by the number of stiffeners. The sheet edges were supported by the outermost stiffeners only, no sheet extending beyond the stiffener flanges. All specimens consisted of from 3 to 5 stiffeners per panel, P having been found to be independent of the number of stiffeners for panels having three or more stiffeners.

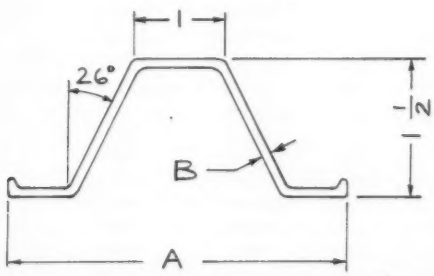

FIG. 3. Dimensions of extruded hat stiffener sections.

Section Ref. No.	Alcoa Die No.	A In.	B In.
9	K14219	$3^{11}/_{16}$	.078
10	K14073	$3^{11}/_{16}$	.089
11	K14074	$3^7/_8$	.117
12	K14075	$3^7/_8$	.135

DETERMINATION OF P_0

As might be expected, P_0 is a function of L, since it represents a hypothetical load carried by the stiffener with no sheet attached but with the same type of restraint as offered by the sheet. In Table 2, values of P_0 are given for various lengths of the stiffener sections listed in Table 1. Values of F_{c_0} and L/ρ_0 are calculated, and plotted in Fig. 4 where the hypothetical stress F_{c_0} is

$$F_{c_0} = P_0/A_0 \qquad (6)$$

For lengths or stiffener sizes other than those listed in the tables, values of F_{c_0} may be picked from Fig. 4 and P_0 obtained from Eq. (6).

TABLE 2

P_0 Values for Various Stiffener Lengths

Section Ref. No.	L, In.	P_0*, Lbs.	F_{c_0}, Lbs./In.^{2}	L/ρ_0	No. of Stiffeners per Panel
1	12.00	3000	30000	33.7	3 to 5
2	25.25	6000	26600	43.3	3 to 5
3	17.75	2700	22700	51.6	4 to 12
4	25.25	2630	19650	62.5	3 to 5
5	36.00	3570	15800	61.5	3 to 5
	25.00	4900	21700	42.8	3 to 5
6	20.00	2600	20000	49.5	3 to 5
7	25.00	6700	23000	44.1	3 to 5
8	20.00	3920	22500	46.2	3 to 5
9	36.00	10300	23500	64.6	3 to 5
	26.00	13200	30000	46.7	3 to 4
10	36.00	12400	25500	65.1	3 to 4
	26.00	15500	32000	47.0	3 to 4
11	36.00	14900	21800	64.2	3
	26.00	19300	28300	46.4	3 to 4
12	36.00	25000	33000	67.0	3
	26.00	30000	39500	48.4	3

* For flat-ended specimens, Ultimate Loads.

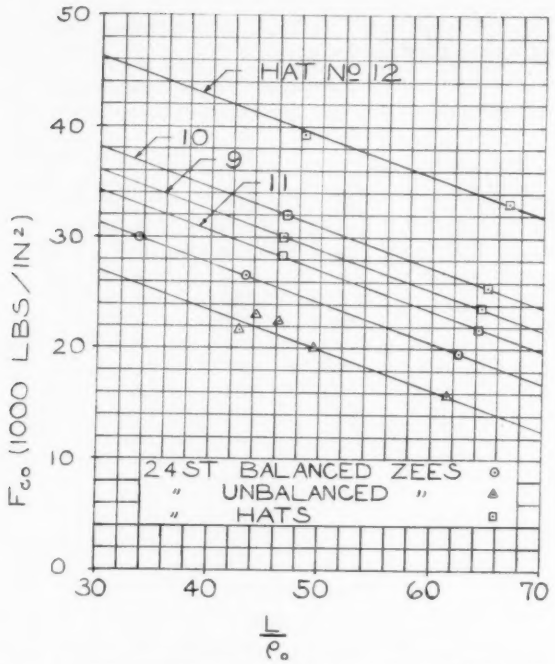

FIG. 4. Ultimate hypothetical column stresses for 24ST extruded stiffeners.

In using the chart of Fig. 4 to obtain F_{c_0}, care must be taken that the section being considered is dimensionally proportional to those represented by the curves. Extrapolation of these curves beyond the range of L/ρ_0 indicated is not recommended. Although they are apparently parallel straight lines within a limited range of L/ρ_0, it would appear logical to conclude that they would become tangent to a Euler curve in the long column range, and would drop off for smaller values of L/ρ_0 in the interaction range, where reduced values of E might have an effect upon the shape of the curves. However, the range of bulkhead spacings represented by Fig. 4 is sufficiently broad for conventional designs. The shape of the curves outside of this range cannot be predicted with any degree of certainty due to insufficient test data.

Illustrative Example

The formula will now be applied to obtain a set of design curves which may be checked with actual test data. Choosing a balanced $1^1/_2 \times {}^{13}/_{16} \times .075$ in. zee stiffener $25^1/_4$ in. long of 24*ST* material (Section No. 2 of Table 1) the values of the constants are inserted in the general formula as follows:

$$P_0 = 6000 \text{ lb. (from Table 2)}$$
$$K = 75000 \text{ (from Table 1)}$$
$$P = 6000 + 75000\, b^{1/3}t \text{ (from Eq. (3))}$$

This equation is plotted in Fig. 1. Comparison with actual test points in Table 3 indicates good agreement.

Average Stress

Eq. (3) may be written on an average stress basis as follows:

$$P/A = (P_0 + Kb^{1/3}t)/A = F_{c_a}$$

But $P_0 = F_{c_0}A_0$ and $A = A_0 + bt$

Hence

$$F_{c_a} = (F_{c_0} + Kb^{1/3}t/A_0)/(1 + bt/A_0) \qquad (7)$$

Inspection of Fig. 4 reveals that within the indicated limits of L/ρ_0, F_{c_0} may be represented by the slope-intercept equation of a straight line

$$F_{c_0} = k - 357L/\rho_0$$

in which the factor -357 has been found to be the slope of the curves of Fig. 4 and applies to all stiffeners investigated regardless of shape. This equation may be rewritten in terms of the usual straight-line column formula for aluminum alloy

$$F_{c_0} = k - (527/c^{1/2})L/\rho_0 \qquad (8)$$

from which the value of c, the end-fixity coefficient, has been determined as $c = 2.18$ for flat-ended specimens. In design, any specified value of c can of course be used in Eq. (8), a common value being $c = 1.5$ for most wing rib-stiffener attachments.

Values of the constant k are represented by the F_{c_0} intercept of the curves of Fig. 4 projected to $L/\rho_0 = 0$, and are listed in Table 1. Eq. (8) may now be substituted for F_{c_0} in Eq. (7) to obtain the average stress equation for a one-inch rivet spacing, as follows:

TABLE 3

Panel Test Loads: $1^1/_2 \times {}^{13}/_{16} \times .075 \times 25.25$ In. Long 24*ST* Balanced Zee Stiffener

b (in.)	t	P Lbs. Ultimate Test Load	P Lbs. Ultimate Calculated	No. of Stiffeners per Panel
2.0	.072	13320	12750	5
"	.064	12080	12000	5
"	.050	10940	10750	5
"	.030	8715	8800	5
"	.025	8280	8250	5
3.0	.072	13930	13750	5
"	.040	10500	10350	5
4.0	.064	13550	13500	5
"	.030	9550	9500	5
5.0	.072	14630	15250	4
"	.050	12400	12500	4
"	.040	11130	11150	4
7.0	.072	16260	16250	4
"	.064	15230	15250	4
"	.030	10400	10300	4
"	.025	9410	9500	4
10.0	.064	16170	16250	3
"	.030	10620	10750	3
"	.025	9970	10000	3

$$F_{c_a} = \frac{[k - (527/c^{1/2})(L/\rho_0) + Kb^{1/3}t/A_0]}{(1 + bt/A_0)} \quad (9)$$

Eq. (9) is plotted in Fig. 5 as a design chart for stiffener section No. 2 of Table 1 on an average stress basis, for a given bulkhead spacing. It is again pointed out

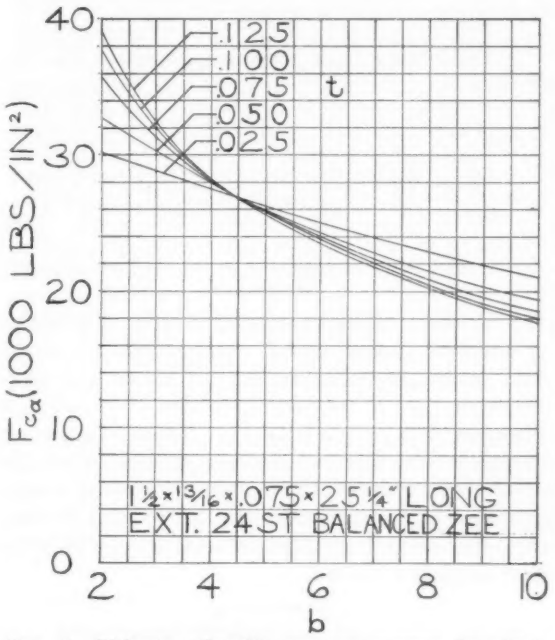

FIG. 5. Ultimate allowable average stresses for sheet-stiffener panels in compression.

that the constant slope term of Eq. (9) does not necessarily hold outside of the range of L/ρ_0 indicated in Fig. 4, or for stiffener shapes not closely related to those of Table 1.

RIVET SPACING

So far, the effects of variation in rivet spacing have not been accounted for in developing Eq. (9), which is strictly applicable only for a rivet spacing of one inch (see footnote of Table 1).

According to Howland,[4] the compressive stress in the sheet between rivets is a maximum when it is equal to a Euler stress. However, below the critical slenderness ratio, the sheet will not develop a Euler stress. A study of available data, covering a variation in rivet spacing ranging from $d = 3/4$ in. to 7 in. for a considerable number of 24*ST* panels stiffened with extruded zee sections, revealed the following points of interest:

(1) When the ultimate load P carried by any given panel was plotted against the rivet spacing d as the only variable, it was found that for the same ratio of d/t, curves for different stringer sections of various panel lengths were all parallel lines.

(2) In the short column range, these curves were approximately straight lines, while in the long column range, they were of the Euler shape.

(3) The slope of the curves in the short column range was approximately 2300 lbs. per in. of variation in rivet spacing d, for a sheet thickness of $t = .072$, corresponding to a slope factor of 478 times the slenderness ratio

$$d/\rho = 2\sqrt{3}d/t\sqrt{c'} = (3.465/\sqrt{c'})d/t \quad (10)$$

Howland assumes that a narrow strip of sheet between rivets receives no support from the sheet on either side, which is reasonable in view of the type of failure usually occuring in the sheet. He then assumes an end fixity coefficient of $c' = 4$ for the elemental strip between rivets, considering the clamping effect of the rivet heads. However, the sheet midway between stiffeners is not restrained at the nodal points by rivet heads, but is free to form waves alternating in direction, at each nodal point adjacent to the region of failure. Hence, only a small increment of the total width of sheet between stringers has fixed-end restraint. Integrated across the entire panel, it might be expected that for usual stiffener spacings and sheet thicknesses, the effective value of c' for the entire sheet width between rivets would be slightly greater than the minimum value of $c' = 1$. This is verified by the empirical slope factor of 478, the usual 24*ST* short column formula having a slope factor of $527/\sqrt{c'}$. The value of c' developed by these test panels is then approximately $c' = (527/478)^2 = 1.2$. It will be slightly conservative to assume the minimum value of $c' = 1$ for the sheet between rivets. The critical slenderness ratio is 78 for 24*ST*, from which the critical value of d/t is, from Eq. (10),

$$(d/t)_{crit.} = 78/3.465 = 22.5 \quad (11)$$

below which the sheet between rivets acts as a short column, and above, as a long column.

The portion of the total load carried by the sheet, from Eq. (3), is the hypothetical quantity $Kb^{1/3}t$ for a rivet spacing $d = 1$ in. Hence, for any rivet spacing less than $d/t = 22.5$ this term becomes

$$Kb^{1/3}t - 527 \times 3.465(d - 1/t)bt$$

and for any rivet spacing greater than $d/t = 22.5$, using the Euler relationship, the term becomes

$$Kb^{1/3}t - (c'\pi^2Et^2/12)(1 - 1/d^2)bt$$

Eq. (9) will now be written in its final form for any rivet spacing, as follows: For $d/t < 22.5$,

$$F_{c_a} = \{A_0[k - (527/c^{1/2})(L/\rho_0)] + Kb^{1/3}t - 1825b(d - 1)\}/(A_0 + bt)$$

and for $d/t > 22.5$,

$$F_{c_a} = \{A_0[k - (527/c^{1/2})(L/\rho_0)] + Kb^{1/3}t - 8.42 \times 10^6bt^3(1 - 1/d^2)\}/(A_0 + bt)$$

End-Fixity

All test data considered in developing the formula were for flat-ended specimens (ends milled parallel). The constant value, 357, for the slope factor of Eq. (9) indicates the end-fixity coefficient as $c = (527/357)^2 = 2.18$, where 527 is the slope factor for $c = 1$ in the straight line column formula for 24*ST*. Several tests were run by the Consolidated Aircraft Corporation for the specific purpose of establishing an end-fixity coefficient for flat-ended sheet stiffener tests. Some specimens were tested on knife edges, the axis of loading being approximately coincident with the neutral axis of the sheet-stiffener combination at failure. Because of the fact that the neutral axis shifts as the load is increased beyond that necessary to cause buckling in the sheet mid-way between stiffeners, it was necessary to adjust the location of the specimens on the knife edges until a maximum failing load was obtained in the testing machine. Specimens of the same sizes were then tested with the conventional flat ends. The results of these tests appear in Fig. 6, indicating that in the short column range of local crippling failures, the stresses developed are not appreciably affected by end conditions. However, in the long column range, the curve for knife-edged specimens is approximately tangent to a Euler curve for $c = 1$ while the flat-ended specimens developed considerably higher stresses in the neighborhood of $c = 2$ or greater. This indicates that $c = 1.5$ is a safe value for conventional sheet-stiffener design.

Conclusions

In consideration of the physical significance of the parameter R it might appear at first glance that the formula does not agree with buckling theory for thin sheet under edge compression, since R is a function of $1/b$, independent of t. However, this is explained by the fact that R is an *average* stress parameter, and if effective width of sheet is used in deriving R to obtain an actual stress parameter R' based on effective area of sheet (acting at the actual stringer stress) instead of total area, then R' becomes a function of t/b, which is consistent with buckling theory. Hence, in obtaining average stresses (or total load per stiffener) where the actual stress variation in the sheet is not being considered, there is no inconsistency in the fact that R as defined is independent of t, and the uncertainty of effective sheet width is avoided.

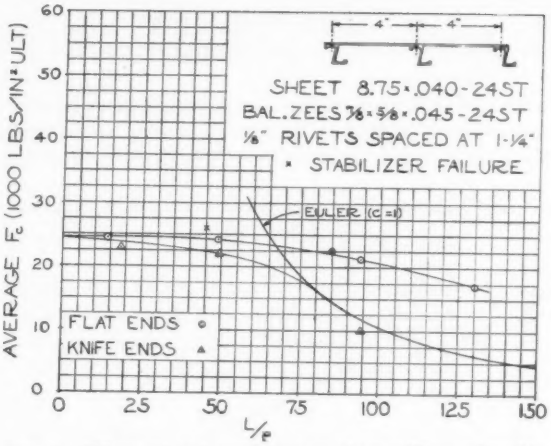

Fig. 6. Effects of end conditions on sheet-stiffener allowable stresses.

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[1] Sechler, E. E., *Stress Distribution in Stiffened Panels under Compression*, Journal of the Aeronautical Sciences, Vol. 4, No. 8, page 320, June, 1937.

[2] Ebner, H., *The Strength of Shell Bodies—Theory and Practice*, N.A.C.A. Technical Memorandum 838, September, 1937.

[3] Timoshenko, S., *Strength of Materials*, Vol. 2, page 604, D. Van Nostrand, New York, 1930.

[4] Howland, W. Lavern, *Effects of Rivet Spacing on Stiffened Thin Sheet under Compression*, Journal of the Aeronautical Sciences, Vol. 3, No. 12, page 434, October, 1936.

Book Reviews

American Wings, by Captain Burr Leyson; E. P. Dutton and Company, Inc., New York, 1938; 214 pages.

There can never be too many books which create pride in American aviation. Captain Leyson has written an informative as well as interesting book giving an excellent idea of the work of military and naval aviation and some acquaintance with practically all of the civil aviation activities. The book is admirable for young men, giving as it does the essentials of the history, experiences, and achievements of aviation.

Of particular interest are the chapters on commercial aviation, with which the author is especially familiar. Stratosphere flight, night flying, parachutes, soaring flight, and private flying are among the subjects treated. It is an exceptionally well organized book.

Science and Mechanisation in Land Warfare, by Donald Portway; Chemical Publishing Co., Inc., New York, 1939; 155 pages, $2.50.

This book was primarily intended as a textbook to be used in connection with lectures given by the author at Cambridge University. While it deals broadly with the engineering aspects of modern warfare, it devotes some pages to the airplane as one of the new developments in tactics. A chapter on the scientific training of the R.A.F. officer indicates the broad scope of the engineering training of an officer in an air force.

It supplies in non-technical language the principles and some of the details underlying the scientific side of the wars of the future.

History of the 135th Aero Squadron (*from July 25 to November 11, 1918*), by Percival Gray Hart; Chicago, 1939; 178 pages.

There have been many statements made that no American made airplanes and no Liberty engines reached the front or were used in combat during the World War. This history will refute such inaccurate statements. The DH-4 and Liberty engines made in the United States were effectively used by this squadron in bringing down German planes.

The book is obviously written for officers who were members of the squadron but is the kind of history that adds credit to the part our pilots took in the conflict.

Institute Notes

Second Rotating Wing Aircraft Meeting

The Philadelphia Branch of the Institute will hold the Second Rotating Wing Aircraft Meeting on November 30 and December 1, 1939 at the Benjamin Franklin Institute in Philadelphia. An interesting and instructive program of papers covering all phases of the subject is being prepared and will be printed in the November issue of the Journal. There will be a joint meeting with aviation clubs and groups on the evening of Thursday, November 30th, at which papers of popular and semi-technical interest will be presented. On Friday, December 1st, there will be two technical sessions with luncheon between and a banquet in the evening. Agnew E. Larson is Chairman of the Planning and Working Committee. The other members of the committee are John S. Kean, Dr. Alexander Klemin, W. Lawrence LePage, Ralph H. McClarren (Secretary), Richard H. Prewitt, and E. Burke Wilford.

Annual Meeting, 1940

The Eighth Annual Meeting of the Institute will be held on January 24, 25, and 26, 1940, in New York. Through the courtesy of Columbia University the meeting will be held in the Pupin Physics Laboratories. The following Sponsors and Alternates have charge of the arrangements for the respective technical sessions.

Aerodynamics I

Eastman N. Jacobs, Sponsor
Dr. W. B. Oswald, Alternate

Aerodynamics II

Dr. H. L. Dryden, Sponsor
Dr. C. B. Millikan, Alternate

Aircraft Design

C. H. Chatfield, Sponsor
Fred Weick, Alternate

Air Transport

J. A. Herlihy, Sponsor
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Fatigue (Aviation Medicine)

Dr. Ross A. McFarland, Sponsor
Dr. Harry G. Armstrong, Alternate

Meteorology

Commander F. W. Reichelderfer, Sponsor
Dr. C. F. Brooks, Alternate

Power Plants, Fuels and Oils

L. F. Hobbs, Sponsor
S. D. Heron, Alternate

Radio and Instruments

Dr. W. G. Brombacher, Sponsor
Dr. L. M. Hull, Alternate

Structures

Prof. John E. Younger, Sponsor
E. E. Lundquist, Alternate

New Officers

At a meeting of the Council of the Institute held on September 29th, Major Lester D. Gardner was elected Executive Vice-President and C. E. Sinclair, Secretary. George R. Forman was elected Business Manager and Joseph J. Maitan, Controller.

Changes in Membership Grades

At the same Council meeting action was taken to merge the grades of Industrial Member and Pilot Member with the grade of MEMBER and changes were made in the qualifications for MEMBER to include applicants formerly classified as Pilot or Industrial Members.

In addition, the stipulation was made that all applicants for the grade of Associate Fellow be recommended by four members of the Institute, two of whom must be Fellows or Associate Fellows.

Gifts to the Archives

In response to the request made by the President of the Institute to members to add to the Archives by sending books, clippings, pamphlets, etc., several valuable and interesting gifts have been received.

Major James H. Doolittle sent two boxes of old clippings. These contained two items, dated December 18, 1903, which describe the first flights of the Wright Brothers at Kitty Hawk. Clippings which appeared a few days later gave the first interviews with the Wrights regarding their invention. From these early dates on, the clippings give a general story of the advance of aviation. They supplement the Berg and Ramsey collections described in the September issue of the Journal. Other members of the Institute who have old clippings will find that they will be of great value to the Archives when carefully filed and made available for reference.

Another gift of importance was received from Albert S. Heinrich. He presented the library with a set of early books on aviation, including the first three volumes of *Aeronautics*, the first two volumes of *Fly*, and the first volume of *Aircraft*. Another rare book in his collection was a translation, by Dr. Hunsaker, of Eiffel's book *The Resistance of the Air and Aviation*.

F. R. Weymouth sent the first two volumes of *Aviation*. The British Air Ministry sent several handbooks on aviation. Many other members have sent books which, with the books received from publishers, have added greatly to the value of the Archives.

In the near future an announcement of the greatest importance to the Archives is to be expected. Apparently members and friends of the Institute are cooperating to expand the present collection, in the belief that complete and well indexed material of this kind will render a valued service to aeronautics.

Changes in Membership

Each month the Journal will announce changes in membership in the Institute. The following changes have occurred since the 1939–40 Membership Roster went to press.

Elected to Member Grade

Bell, Stanley Alfred, M.I.Ae.S.; Chief Engineer, Hughes Aircraft Co.

(*Continued on next page*)

Corwin, Elbert Franklin, M.M.E.; M.I.Ae.S.; Instructor, Dept. Aero. Eng., Rennselaer Polytechnic Inst.; Managing Director, Mt. Whiteface Meteorological Observatory.

Hospers, John Johannes, M.I.Ae.S.; Lt., U.S.N.R.; U.S. Navy Field Svc. Representative, Vought-Sikorsky Aircraft, United Aircraft Corp.

Houghton, Howard David, M.I.Ae.S.; Chief Draftsman, Douglas Aircraft Co.

Koriagin, Vsevolod Basil, M.S. in Ae.E.; M.I.Ae.S.; Senior Engineer, Lockheed Aircraft Corp.

Perry, Julian Packard, B.S. in Ae.E.; M.I.Ae.S.; Chief of Structures, Pitcairn Autogiro Co.

Pratt, Wallace Everette, M.I.Ae.S.; Director, Standard Oil Co. of N.J. (See W.W. in A.; A.M. of S.)

Reisner, Joseph Henry, M.I.Ae.S.; Sales Engineer, Aircraft Accessories Corp.

Rummel, Robert Wiland, M.I.Ae.S.; Chief Engineer, Rearwin Aircraft & Engines, Inc.

Sadler, Everit Jay, B.S.; M.I.Ae.S.; Vice-Pres., Standard Oil Co. of N.J.

Seamons, Joseph Paul, B.S. in C.E.; M.I.Ae.S.; Chief Engineer, Solar Aircraft Co.

Sharples, Philip Triest, B.S.; M.I.Ae.S.; Pres., The Sharples Corp.; Pres., Sharples Solvents Corp.

Wynne, John S., LL.B.; M.I.Ae.S.; Attorney-at-Law and Aviation Adviser.

Branches

Los Angeles. A dinner meeting of the Branch was held on September 8th. In a paper entitled "Notes on the Design of Big Boat Hulls," E. G. Stout of the Consolidated Aircraft Corporation summarized new research on the effects of hull dimensions, and described the Consolidated method of building and testing dynamically similar flying-boat models. The paper was illustrated by a reel of motion pictures showing the model tests. A second paper was presented by Dr. W. L. Howland of the California Institute of Technology on "What Can We Expect from X-Ray Inspection?" The progress of current research on quantitative measurement of imperfections in castings and forgings and the correlation between X-ray indications and physical properties were reported. The meeting was attended by about 100 members.

Rensselaer Polytechnic Institute. A meeting of this Student Branch was held on September 21st. Prof. P. E. Hemke spoke on the C.A.A. flight training program emphasizing the fact that it is a civil rather than a military venture. Robert Aldrich spoke on flying at the Troy Airport. Prof. A. U. Fairbanks gave a summary of the proposed program for the year, and Mr. Beil and R. J. Cox described the activities of the "Glider Club."

Seattle. A meeting of the Branch was held on August 23rd. Joseph Ables, Flight Operations Manager for United Air Lines, presented a paper on "What Airlines Desire in Aircraft." Captain Felix Jones, Pilot for United Air Lines, gave a companion paper on "What Pilots Desire in Aircraft." An interesting discussion followed the presentations. 148 members and friends attended the meeting.

Book Reviews

The Air Force of To-Day, by E. C. Shepherd; Blackie and Son, Ltd., Glasgow, 1939; 206 pages, 5s.

American readers of *The Aeroplane* will take an especial interest in this book, since it will acquaint them with the style of the new Editor who is to succeed Mr. C. G. Grey. Mr. Shepherd has been aeronautical correspondent for *The Times* of London for many years. After graduating from Oxford he served with the R.A.F. during the war, and has continued to make flights with the service squadrons on some of their hazardous as well as routine operations.

The title of the book would give the impression that its subject matter is confined to the Royal Air Force as it is today. It has, however, a much wider scope. Sir Kingsley Wood writes: "In this book Mr. Shepherd has produced an absorbing and informative account of the development and work of the Royal Air Force and of the part which it plays in our scheme of National Defense."

To understand the present status of the R.A.F. it was necessary to trace its beginnings and vicissitudes before and during the war. This Mr. Shepherd does without the bias of a proponent for a centralized air force. He does show how the flying services were limited in their operations by the Army and Navy and the difficulties encountered by General Trenchard in his attempt to give air power a function other than a service of observation and communication subordinated to the older arms.

These early ideas on aerial strategy and tactics laid the foundation for the new conception of the employment of aircraft, *i.e.*, to carry attack beyond the military and naval objectives to the industrial and political centers of an enemy. One of the outstanding features of the book is the character study of Lord Trenchard, who will always be regarded as one of the most farsighted leaders military aviation has produced.

In his study of the development of the Air Force, Mr. Shepherd discusses many of the debatable problems of air power which only a major utilization of this new arm can solve. He quotes T. E. Lawrence in comparing bombers with fighters, "Range is more to strategy than force" and gives both sides of the argument.

He gives a clear account of the relationship of the British Navy to the Royal Air Force and shows that, while the Navy has been given command of all ship borne aircraft, the R.A.F. still retains the sea patrol squadrons, procurement, and training services.

It will be surprising to many to read that the R.A.F., with its 70,000 officers and men, to say nothing of the Auxiliary Air Force, the various Reserves, and the R.A.F. Volunteer Reserve, is a bigger force than the British Army. More money is spent on the R.A.F. than on the Army.

The book is much more than a study of one air force. It gives the philosophy behind all the work of military aviation of today and uses the experience of the R.A.F. to interpret it. It is a book that will be read with great interest by the commands of air forces in other countries, as well as in Great Britain.

A.R.P. and High Explosive, by Major-General H. L. Pritchard; Duckworth, London, 1938; 51 pages, 1s.

Protection against high explosive bombs is the most difficult as well as the most expensive of all forms of air raid precautions. General Pritchard supplements the many booklets by the A.R.P. Division of the Home Office, by explaining how destructive H.E. bombs can be and how the individual can be protected. He then gives designs for air raid shelters which will be bombproof.

Reading this book, which is written by an expert in his field, indicates the impossibility of providing adequate protection for any large number of people against air raids when large size bombs are dropped.

Book Reviews

The Aircraft Year Book for 1939, edited by HOWARD MINGOS; Aeronautical Chamber of Commerce, New York; 580 pages, $5.00.

The twenty-first edition of this indispensable annual of aviation in the United States exceeds all previous editions in size and completeness. The whole range of American aeronautics for 1938 passes in review both in text and in pictures. The contents are based on information obtained from official sources and can be regarded as technically accurate.

In the chapter on "Air Power in 1938" emphasis is placed on the role of bombing planes in international affairs. "The most persuasive force in international relations in 1938 was the raiding airplane. It dominated the political thoughts of the world."

Of great significance are excerpts from the Annual Report of the National Advisory Committee for Aeronautics and recommendations which show the need for the earnest and serious support of scientific research and the encouragement of experimental engineering development directed toward putting the results of laboratory research into useful form.

The sections on the government aviation services, the industry, aeronautical organizations, and activities represent standard reference sources in these fields.

As in other editions, the drawings of new American aircraft and power plants are excellently done. This part of the book is a continuing history of aeronautical engineering in the United States. The statistical sections are, as usual, invaluable.

The editor and all those who have contributed to the preparation of the book merit the sincere appreciation of all those who wish to keep abreast of the technical progress made in the United States in the field of aviation.

Jahrbuch 1938 der Deutschen Versuchanstalt für Luftfahrt E.V.; Berlin-Adlershof, 1939; 692 pages.

It is of course not possible to do justice to a book of this kind in a review of reasonable length. It contains the collected research reports of the D.V.L. for the year 1938. A brief description of the subject matter of the various sections will give some idea of its scope.

It begins with a 13 page description of the organization and activities of the D.V.L. There follow 92 papers by members of the various Divisions and Institutes comprising the organization.

General contributions on aircraft include papers on the drag of radiators, the minimum resistance of high speed airplanes, the induced resistance of heavily loaded propellers of a finite and infinite number of blades, considerations regarding propeller drives for high speed airplanes, and new instruments for aeronautical research.

Included under the heading "Aerodynamics Institute" are papers on wing oscillation experiments, three-component measurements on parachute caps, and axial thrust measurements on large propellers.

One paper, on the influence of deflection and keeling on landing impact is included under the Institute for Marine Aviation.

Contributions by the Institute of the Mechanics of Flight include remarks on the results of Prandtl's wing theory, fundamentals and results of the lifting line theory, lift distributions and aerodynamic coefficients for elliptical and non-elliptical wings, results for elliptical wings with step-wise constant and linear variation of angle of attack, pressure distribution over a wing of any shape, flight experiments to determine the air forces on airplanes during violent maneuvers, turning and rolling oscillations of airplanes, frequency of occurrence of various loads on airplane wings, and maximum load and frequency of gust loads on commercial airplanes.

Contributions under Structures include effect of stiffness variation on the strength of statically indeterminate wings, strength variation due to breakdown of a single part of wings of more than one spar, experiments with stiffened cylindrical shells loaded at one point, use of the energy method in stability problems, analysis of flat sheets above the buckling limits, and an analysis of the influence of size on the flutter of wings.

Papers in Materials give the influence of casting defects on the strength of light metal castings, the fatigue strength of thin walled tubes, tensile strength of chromium-molybdenum steel tubing under varying stresses, influence of cross-section on the tensile strength of soft steel castings, diffusion of silicon in steel, recrystallization and recrystallization temperature of Aluminum-Magnesium alloys, effect of the specimen selection on the strength characteristics of light metal castings, dynamic strength characteristics of light metal alloys at low temperatures, notch effect and influence of cold shaping on durability, determination of the thickness of Eloxal layers, and the application of plastics to airplane construction.

General contributions dealing with Power Plants include test stands for high altitude research, altitude performance of engines based on performance measurements under ground conditions, super-sonic ducts and ballistics, and the shape of light airplane engine pistons.

The next section includes papers on altitude performance of a high speed single cylinder engine, construction and operation of superchargers, the gyro supercharger, characteristics of inline or multi-stage superchargers, supercharger drives, gas turbine construction, investigations of roller bearings at high rotational speeds, and the new single cylinder test installation of the D.V.L.

The following section on engine theory and thermodynamics includes papers on precautions to improve power consumption of the Otto engine, performance and economy of overloaded Otto-cycle engines, reactions of overloaded Diesel engines, altitude behavior of pre-chamber Diesel engines, jet developments and the size of droplets in fuel injection, control of high exhaust gas temperatures through cooling of exhaust gas turbine, stroboscopic measurements, an electrical switch for operating a cathode ray tube and drum chamber, and experiments on wires in tension.

Papers on propulsion include oscillating requirements and durability of Electron-propellers, propeller bending oscillations, gyroscopic effect of the propeller on the natural frequency of an engine mount, use of soap films for the solution of stress problems, optical measurements of tension, and an electro-magnetic indicator.

There follows a paper on fundamentals of laboratory and engine testing of lubricating oils.

The next section, on Gasdynamics, includes papers on cooling in high altitude flight, and heat transmission and generation from profiles and plates.

A section on physical problems includes articles on 3 meter waves, double frame bearing, beam groups with rotating phase, the sound field of a propeller, noise reduction in airplane cabins, electrical installations on airplanes, clamp connections for cables of light metal strands, theory of the cross-coil apparatus, pendulums with long period, and effects of moderate vibration on measuring instruments.

Papers on photography describe production of highly sensitive infrared emulsions of high quality, and a method for increasing the sensitivity of silver halide gels.

A section on aviation medicine comprises two papers, on effects of centrifugal forces on blood pressure and pulse frequency, and the influence of vibration on the human organism.

Conquest of the Skies, by PETER MERIN; John Lane, The Bodley Head, London, 1938; 312 pages, 12s. 6d.

This is another history of flight but it is presented in a new manner. It is particularly interesting in the early chapters,

which treat the legendary, mythical, and religious aspirations of man to fly. Interest is sustained by "thumb-nail sketches" of many great flights and comparisons between the early and more recent achievements.

The literary style of the book sets it apart from other historical works on aviation. The writing is at times brilliant and the motives behind and the results of the various accomplishments are interpreted from a broad cultural standpoint. It may not be too much to say that it is the first fully imaginative history of the idea of human flight. It certainly gives to the long line of theorists, visionaries, experimenters, inventors, and pioneers full credit for lofty and selfless idealism unadulterated for the most part by any thought of gain or power.

Bombs Bursting in Air: The Influence of Air Power on International Relations, by GEORGE FIELDING ELIOT; Reynal and Hitchcock, New York; 173 pages.

Some of the earlier writings and lectures of Mr. Eliot did not seem to be very sympathetic toward the potentialities of a strong air force. Possibly more careful investigation and the experiences of recent employment of aircraft have given him a better understanding of air power. Certainly there is little in his present book that the most ardent aviation proponent could disagree with. He even goes so far as to make the sweeping statement: "The history of civilized mankind shows us but three such revolutionary military inventions: discipline, gunpowder, and the airplane."

Such innovations as steam, the submarine, and armor are not included. The extremely important place he gives the airplane is, briefly, that for the first time in warfare the means of striking directly at the seat of the power of a nation, the citizens, the capital, the industrial, commercial, and political centers are available without first having to overthrow the armed forces which protect them.

It would be easy to differ with the author's estimate of the airplane strength of European powers. The figures are as of March 1, 1939, and would seem to be on the conservative side. However, since all published figures on this particular subject are rough estimates and since numbers represent only one of the factors determining air strength, one guess is as good as another.

The production estimates are not nearly as reliable as the strength figures. If Great Britain is only producing 400 airplanes a month it is surprising, and if they can only produce 600 a month on a war basis, the shadow factory scheme has not been as successful as we have been led to believe. Also, if the Soviet Union is producing only 250 airplanes a month it is difficult to believe their full strength is 5000, first line and reserve. It is a field for interesting speculation and Eliot's attempt is of interest because it may be assumed that he had access to good sources of information.

There can be little controversy with the claim that it would require from 600 to 1200 planes to carry out an hourly attack on a large and well-defined target. Such numbers are now common talk in aviation circles.

The chapter on the possibility of the United States being attacked from the air gives the latest thought of military experts and, while reassuring, does open possibilities that our defense forces have to consider.

The utilization of air power for international blackmail merely shifts this diplomatic force from navies to aircraft. Formerly the threat of blockade or of destroying lines of commerce could only be effective with countries having sea power or trade. Since coast lines are obliterated by air power, the threat of a bombing can be used against countries regardless of their location.

The conclusions of the author as to the extent of the air power needs of the United States is a review of the best thought as expressed by our aviation leaders, military, naval, and civilian.

Bombs Bursting in Air is a timely contribution to the growing literature on air power. Conservative and constructive in tone, well fortified with facts and figures, and presented by a skillful and informed writer on military and naval matters it will be helpful in arousing the American public to the potentialities of this new development in arms.

The Royal Air Force Year Book, 1938, compiled by LEONARD BRIDGMAN; Gale and Polden, Ltd., Aldershot, 1939; 232 pages.

No volume hitherto published has given such a comprehensive view of the Royal Air Force and the air forces of the components of the British Empire. Of particular interest at the moment are the characteristics of the leading British aircraft which are given in surprising detail.

Chapters on the role of the Air Force and the comparative budgets or estimates since 1929 give an excellent idea of the great expansion that has taken place during the last ten years. The operations at home and abroad, the organization of the Air Ministry, and a history of each R.A.F. squadron add to the completeness of the Year Book.

The Fleet Air Arm is described in a separate chapter which explains the new status of this service and gives descriptions of the aircraft carriers of the British Navy. The history and organization of the Air Forces of Canada, Australia, New Zealand, South Africa, India, and Eire as well as those of the Crown Colonies of Ceylon, Rhodesia, Kenya, and the Straits Settlements are presented briefly.

Leonard Bridgman has again compiled a handbook which will be useful in following the activities of the R.A.F. during the present war, in which air power is expected to play such an important part.

On Top of the World, by LAZAR BRONTMAN; Covici-Friede, New York, 1938; 343 pages, $3.00.

Dealing with the 1937–38 Soviet expedition to the North Pole, this book describes an unparalleled aviation achievement—the transport of a scientific party and complete equipment for a long stay at the North Pole. Backed by the resources of the U.S.S.R., Professor Schmidt, the leading Russian exponent of Arctic exploration and a scientist of reputation, was given a free hand in organizing the expedition. Four men, headed by Ivan Papanin, whose interest in the Arctic was aroused when he traveled to Franz Josef Land to take the mail from the airship Graf Zeppelin, were to establish a camp as near the North Pole as possible and make scientific studies and observations of the drift of ice floes.

Four four-engined specially designed cargo airplanes and a twin-engined scout plane were built to meet the exceedingly difficult requirements of a polar flight. Some of the greatest Soviet pilots were to fly the party and equipment to an aerdrome of ice near the Pole.

The first half of the book, written by a journalist who accompanied the expedition, relates the story of the flight to the base, about fifty miles from the Pole. The latter part describes the many months of scientific work by Papanin and his associates, and their eventual rescue off the shore of Greenland by Russian ice breakers.

The story of the flights from Moscow to the last land base on Rudolph Island and the establishment of headquarters near the Pole have been described in newspapers and magazines and shown in the news reels. However, none of these give the intimate and dramatic story that is to be found in this book. A keen observer and an experienced writer, Brontman not only presents the facts but adds human interest to the story. The reader experiences the anxiety of preparation, the fears and dangers of the flights north to the several intermediate landings, the impatience with the bad weather conditions, and, finally, the thrill of successful accomplishment. When the book is put aside there remains the memory of an aviation accomplishment which will probably not be excelled for many years to come. As an

indication of the sturdiness of Russian airplane and engine construction, the determination and skill of Soviet aviators, and the sacrifices that men are willing to make for scientific research and the glory of Soviet ideals, the book is outstanding.

The "Empire" Marine Aircraft Deck Log Book; Brown, Ferguson and Sons, Ltd., 1939; about 80 pages, $1.50.

For operators of air transport this log book will be a useful guide to the preparation of such data as may be required by the management and engineering departments for the statistical analysis of flights. It is designed to be used by flying boats on the British Empire routes, though it would be useful to any air transport company operating over great distances. Any company interested may obtain a sample sheet by writing to the Institute.

The International Air-Post Album; Scott Publications, Inc., New York, 1939 edition; about 400 pages, $7.50.

The collecting of air mail stamps and covers has almost become an industry in itself. If reliable estimates could be obtained on the extent to which philatelists have contributed to the revenues of air transport, particularly to first flights, the figures would undoubtedly be surprising.

The 1939 edition of this album confines its scope to air mail stamps. Many illustrations of stamp designs are included. It contains spaces for every major variety of Government issue of Air Post Stamps listed in the Standard Postage Stamp Catalogue and adds statistical data, dates of issue, and historical information on outstanding flights.

The pages are $10 \times 11^1/_2$ inches and are conveniently bound in loose leaf form.

Standard Catalogue of Air Post Stamps; Nicolas Sanabria, Inc., New York, 1939; 661 pages.

The ninth edition of this standard catalogue gives the stamp collector a complete guide to all air post stamps in the world up to 1939. The inclusion of semi-official air post stamps and a list of flight covers of U.S. pioneer flights make the book particularly complete.

Aviation, or, Human Flight Through the Ages and **Aviación, el Vuelo Humano a Través de los Siglos,** by ERNEST E. WALKER; Aeronautics Education Foundation, Washington, D.C., 1939; 132 pages.

The author has condensed into this small book a readable history of flight. Starting with the ancients and tracing the technical development of the airplane the author proceeds to give the leading achievements as exemplified by famous flights.

He has translated the book and brought out editions in English and Spanish simultaneously.

As a presentation of the essentials of the history of flight this work gives a clear picture of man's conquest of the air.

Straightaway Review, 1938; Straight Corporation, Ltd., 1938; 70 pages.

Mr. Whitney Straight has, since 1935, been developing an integrated service for British civil aviation. He has built a chain of airports and organized flying services and schools of instruction. This book is the first annual edition of a monthly of the same name and gives the scope and activities of the Straight Corporation. Its style of presentation could well serve as a model for any company engaged in aviation activities.

Lightplane Flying, by WOLFGANG LANGEWIESCHE; Pitman Publishing Corporation, New York, 1939; 213 pages, $2.50.

At a time when so many young men are preparing for training in light airplanes, a book such as *Lightplane Flying* will be not only useful but highly practical. The author does not deal in generalities about flying but gives facts, figures, and costs. He introduces the novice to this comparatively new type of airplane and gives convincing statements as to its economic and safety features.

The most intriguing part of the book will be the explanation of the many inexpensive ways of learning to fly. The old idea of the high cost and long period of training required for flying instruction is changed to a new and simple plan which seems almost as easy as learning to drive an automobile.

The book will supplement flying instruction and save much valuable time, since it outlines what the student must learn and gives many valuable hints on flying technique.

The manufacturers of light planes will find the book a most attractive sales manual. It will change the attitude of many people toward flying. Advice on how risks may be minimized, expenses cut, instruction easily secured, and the many opportunities for pilots are given.

Simplified Flying, by BOB SWIFT and AL KNOUFF; Aircraft Directory, Athens, Ohio, 1939; 51 pages, $1.00.

This booklet is written by a pilot for whom broad claims are made regarding the brief interval of instruction required before his students will solo. It does not purport to be a complete flying course but rather gives the bare essentials required of a student while he is taking his first instruction. With this limitation it is readable, factual, and informative, and is calculated to allay what fears the embryo pilot may have during the early hours of his instruction. However, considering the law of supply and demand, the number of books on piloting which are available should bring the price of this as well as others down.

The Complete Flying Course, by N. ROY HARBEN; C. Arthur Pearson, Ltd., London, 1938; 92 pages, 5s.

This handbook is unique in its presentation. On the left hand pages the air lessons are given, and, on the right, ground lessons explaining the maneuvers appear. Action, effect, remarks, and explanations are given in parallel columns with a diagrammatic sketch of each maneuver. The material is divided into specific lessons and the student is advised to read the text before a given lesson is executed.

The combination of diagrams and explanations makes each maneuver particularly clear. The book should serve its purpose admirably.

Learning to Fly, by FRANK A. SWOFFER; Sir Isaac Pitman and Sons, Ltd., London, 1939; 169 pages, $2.25.

When a book on flying instruction survives the test of ten years' practical use and appears in its fifth edition, its reputation is obvious. Mr. Swoffer, who has been a flying instructor for many years, has brought the chapters up-to-date and incorporated in them the observations of his students. The result is a clear and direct instruction book which gives a beginner the rudiments of the art. It should be in great demand during the period of expansion of our pilot personnel.

Fly With Me, by VICTOR RICKETTS; Hurst and Blackett, Ltd., London, 1939; 94 pages, 1s.

If a flying instructor had a dictaphone by his side on the ground and in the air while he was teaching a pupil and had the records transcribed and printed in a booklet, the result would be such a book as *Fly With Me*. It dramatizes the mistakes of the pupil more than the usual manual of flying, and, as it claims, gives a description of "the technique of flying learned from your armchair."

Aeronautical Reviews

These brief reviews of recent articles on aviation subjects are published by the Army Air Corps for the information of its officers, and are printed here each month by permission of the Chief of the Air Corps

Aerodynamics

The Italian Research Station. Layout of Guidonia research establishment and equipment are discussed and illustrated. Characteristics of the following are given: Fiat G.50 single-seater fighter monoplane (840-hp. Fiat A.74 R.C.38 engine, maximum speed 304 m.p.h. at 12,500 ft.); Macchi C.200 single-seater fighter monoplane (840-hp. Fiat A.74 R.C.38 engine, maximum speed 313.6 m.p.h. at 15,750 ft.); Fiat C.R.42 single-seater fighter biplane (340-hp. A.74 A.C.38 engine, maximum speed 271 m.p.h. at 13,100 ft.); and the Fiat A.74 R.C.38 engine. Reference is made to the Nardi F.N. 305 trainer, the Piaggio three-engined high-speed experimental, the four-engine bomber of medium size, and the small high-wing Breda 88. Area of flaps on these airplanes are briefly discussed, and construction of the Savoia-Marchetti S.85 twin-engined single-seater midwing dive bomber is mentioned. Many photographs taken at the first International Conference of the Aeronautical Press are included. *Aircraft Engineering*, July, 1939 pages 269–272, 280, 20 illus., 4 tables.

Aeronautical Research. Uneven progress in research ascribable to the inherent difficulty of aerodynamics is shown in the report of the Aeronautical Research Committee for the year 1938, according to this editorial. Research results obtained in the reduction of aircraft resistance and improvement of stability and control which are in the forefront of the report are discussed in detail. Increase in experimental equipment including five new wind tunnels under construction at the National Physical Laboratory, and a 10 × 7 ft. tunnel for the study of phenomena at wind speeds up to 600 m.p.h. at the Royal Aircraft Establishment are referred to.

The free-flight tunnel now being developed in the United States is said to be presenting a good deal of experimental difficulty. Before steps are taken to adopt the method in England, a more comprehensive trial is being given to a promising technique in which a model undergoing wind-tunnel test is supported with a restricted number of degrees of freedom. Comments are given also on research results obtained in other branches of aeronautical engineering. *Engineering*, August 11, 1939, pages 171–172.

The Work of the D.V.L. F. Seewald. Paper previously abstracted from preprint, and discussions by Sir Henry Tizzard, H. Roxbee Cox, E. F. Relf, G. P. Douglas, Major B. C. Carter, and others, as well as the author's reply. *Jour. Royal Aeronautical Soc.*, July, 1939, pages 508–545, 23 illus., 1 table.

Aircraft Design

An Elementary Study of the Spin. J. H. Crowe. Yawing moment due to fin and rudder; weathercock stability; incipient spin; sequence of events when the ailerons are put over to stop the initial roll; slots to preserve stability, and ailerons and interceptor gear for control; method of calculating the steady spin assuming that all data needed are available; example of spin calculation; types of spin; mass distribution influence on the steady spin; spinning properties of monoplanes; effect of changes in wing loading; the inverted spin; problem of satisfactory recovery from the established spin; rolling and pitching couples; physiological effects; recovery procedure; and pitch oscillation. Concluded. Very long bibliography is included. *Aircraft Engineering*, July, 1939, pages 273–278, 3 illus., 1 table, 5 equations.

Simultaneous Equations. A. R. Collar. Method recently published by Capt. J. Morris for the solution of linear algebraic equations is considered, and it is shown how the statement of the method and the proof of its convergence may be greatly condensed by the use of matrices. An alternative computational scheme is presented which involves far less recording of numbers, and therefore less risk of error, than that proposed by Morris. *Aircraft Engineering*, July, 1939, page 279, 9 equations.

Stress Analysis and Structures

Efficient Utilization of Aircraft Tubing. J. Mueller. Since heat treatment of the welded structure of chromium-molybdenum steel aircraft tubing is not feasible, a method has been patented in Germany whereby each section of tubing is welded to a short but thicker reinforcing end tube before heat treatment. Welding of the reinforced section after heat treatment localizes the soft heat-affected zone in the thick reinforced end tube. Welded tubular assemblage thus utilizes the full strength of the thin heat-treated tubing. The wall thickness of the end section is such that the section may be designed on the basis of annealed steel without reducing the strength of the structure. Under static tensile and compressive stress (fatigue tests not having been made) it is obvious that the reinforced tubing meets requirements. Column action of the reinforced tubing could not be predicted but was found by test to be satisfactory. Results show that column strength of welded tubing made by the new method is superior to that of unreinforced tubing up to the l/r ratios of 75 most commonly used in aircraft. Tests were made at the Focke-Wulf Aircraft Company, Germany. Abstract from *Luftfahrtforschung*, January 10. *Welding Jour., Welding Res. Sup.*, August, 1939, page 270, 2 illus.

Fatigue Problems in the Aircraft Industry. K. Arnstein and E. L. Shaw. Possible causes of fatigue phenomena in airplanes and airships, sources and probable occurrences of dynamic loading, and the contributing factors which produce and accelerate fatigue. Cyclic and non-cyclic load variations on parts of an aircraft and the factors which cause local increase in stress and contribute to fatigue are considered. Problems of fatigue of girders, spars, struts, wires, cables, pulleys, joints and fittings, as well as container and power-plant problems are discussed.

The author recommends a completely automatic instrument which would record directly all the maximum tensile and compressive stresses ever reached on an aircraft, as well as the number of cycles of several different ranges of stresses. Instrument should be connected at all times to the aircraft and not require attention more than a few times a year. An instrument approaching these requirements is being developed by the Goodyear-Zeppelin Company for the U.S. Navy on the principle suggested by L. H. Donnel which is to utilize the strain in the member to actuate a number of ratchets attached to counters. A few details are given. *Metals & Alloys*, July, 1939, pages 203–209, 10 illus.

Structural Research in Aeronautics. A. G. Pugsley. An appreciation of, and some comments on, A. G. Pugsley's article in the June issue are given by J. D. North. *Aircraft Engineering*, July, 1939, page 280.

Aircraft Maintenance

Check and Double Check. Capt. C. S. Irvine. Maintenance methods of the U.S. Army Air Corps are discussed in great detail. *Aviation*, July, 1939, pages 24–27, 6 illus.

Maintenance Training. W. M. Thompson. Special course of instruction at the Maintenance Engineering School of Parks Air College is described in detail. *Aviation*, July, 1939, pages 32–34, 7 illus.

Servicing Our Flying Fleets. Comm. F. B. Stump. Maintenance of aircraft of the U.S. Navy Bureau of Aeronautics is described with special reference to problems in corrosion, barnacles, engines, and instruments, and the relation of maintenance and research. *Aviation*, July, 1939, pages 28–31, 5 illus.

MAINTENANCE EQUIPMENT

Aviation's Maintenance Note Book. Shop gadgets and shop practices involving new and useful ideas are illustrated with a line or two of explanation, including: apron service jacks; maintenance of wheels and brakes; airplane overhaul; work stands; devices for handling and testing engines and propellers; engine-overhaul apparatus; electrical and radio maintenance equipment; instrument-overhaul devices; and methods of overhauling hydraulic systems. *Aviation*, July, 1939, pages 35–50, 121 illus.

Maintenance in Non-Scheduled Operation. Devices developed at the Booth-Hemming maintenance base, at the Bredouw Airmotive Corporation repair shop, and at the California Flyers, Inc. base. *Aviation*, July, 1939, pages 51–53, 90, 23 illus.

A Retractable Tap. Phillips telescopic taps or Phillescopes, used in Short Sunderland and new G-class flying boats, and by Hawker and Blackburn aircraft companies. Until the tap is fully extended no water can escape. Cylindrical fixed portion of the tap, has a flange for attachment and extends inwards into the tank. A sleeve contains the outlet port and slides inside the fixed portion. When tap is pushed in for closing it can be turned through nearly 90° to lock it and seal a washer firmly against an adequate bearing surface. Brief note and drawing. *Aeroplane*, July 26, 1939, page 132, 9 illus.

Aircraft Manufacture

The Economics of Aircraft Production. O. Oeckl. Principles on which the designing of the plant and equipment necessary for aircraft production should be based are discussed with special reference to the work of the Henschel aircraft factory. With careful preselection of the method of design and, particularly, construction of the jigs, it is shown that the cost of jigging and tooling can be lessened by making them suitable for a number of different components. Development cost of the introduction of a new type of airplane can thus be greatly reduced and the inevitable delay in turning over to its production can be very much cut down. Construction of solid, and even massive, types of jig, which are obviously advantageous when production is envisaged, need not necessarily be uneconomical if the foundations are designed in such a way as to be capable of being used for a number of different types of superstructure so that they can be readily adapted to take new components.

Chart shows that something approaching true mass-production methods of the automobile factory has been attained, or at any rate how the curve is being gradually brought nearer to it. Photographs of various jigs and a table indicating the possibility for the repeated use of jig parts are included. Translation. *Aircraft Engineering*, July, 1939, pages 287–290, 9 illus., 2 tables.

Flush Riveting Considerations for Quantity Production. D. R. Berlin and P. F. Rossmann. Paper and discussions on the advantages of the Martin 115-degree flush-rivet head (B. C. Boulton), and on the Douglas technique of flush riveting, in comparison with Curtiss Technique (V. H. Pavlecka). *S.A.E. Jour.* (*Trans.*), August, 1939, pages 325–333, 27 illus., 3 tables.

Aircraft Refuelling in Flight

The Flying Petrol Station. An account of a demonstration of refueling the Canopus flying boat in the air from the Harrow tanker refueling plane. *Aeroplane*, August 2, 1939, page 167, 2 illus.

Refuelling in Flight. Preparations have been made by Flight Refuelling, Ltd., for the refueling operation to be carried out in the air on the aircraft to be employed in the British Atlantic air-mail service on their return journey from Botwood. Precautions to be observed against electrostatic effects which arise from differences in potential between the two machines, from frictional electricity in the pipe lines, from electrification by splash in tanks, and from receiver and nozzle coupling are pointed out. Equipment available at present for experimental purposes and for establishing the Atlantic air-mail service is described in detail. It includes four "Harrow" bombing machines and an Armstrong Whitworth A.W. 23 airplane equipped for both receiving and tanking for experimental purposes. Long article also covering: the process of refueling in the air; historical review of flight refueling development; theoretical considerations; methods of assisting take-off; refueling as applied to an airliner (performance, performance after engine failure, stability, and effects on payload and range); and methods of jettisoning fuel. *Engineer*, August 4, 1939, pages 122–126, 17 illus.

Aircraft

A Type Display at Brussels. At the "Exposition des Prototypes," held in connection with the Brussels Aeronautical Exhibition, there were no prototypes on view, as all were fairly well known, although some had not been shown to an international public before. Comments are given on flight exhibits of the following: Fokker G.1 twin-fuselaged formidably armed airplane (two Bristol Mercury engines); Klemm 35 (90-hp. Hirth engine); Koolhoven F.K.52 two-seater biplane; Junkers 87 dive bomber; Hanriot 230 advanced trainer; Arado 79 two-seater; Hummond two-seater (45-hp. Zundapp engine); and the Focke-Wulf Condor and Junkers Ju 90 four-engined airliners. *Aeroplane*, July 26 1939, page 110, 1 illus.

GERMANY

Dornier Do-26 Long Range Flying Boat. Dornier Do-26 catapultable long-range flying boat has wing-tip floats retracted into the wings in flight, and is intended to fly the North Atlantic. Four Junkers Jumo 12-cylinder heavy-oil engines, each developing 600 hp., are placed in tandem, the forward engine driving a tractor propeller directly, and the rear engine a pusher propeller through gearing. To protect the rear propellers against spray from hull chines when taking off, the rear portion of each mounting, together with rear engine, shaft, and propeller, can be tilted up through an angle of 10°, equivalent to a vertical movement of the propeller of 15.6 in. Mountings assume their normal position as soon as the boat is in the air and the two halves of the mounting constitute a continuous streamlined structure in normal flying position. Wing span 98.5 ft. Overall length 80.5 ft. Overall height 22.5 ft. Useful load 21,640 lb. Gross weight 44,090 lb. Maximum speed at sea level 208 m.p.h. Cruising speed 193 m.p.h. Landing speed 68.4 m.p.h. Maximum range 5600 miles. Long description with detailed three-view drawing, and photographs of the interior. *Aero Digest*, August, 1939, pages 138–141, 11 illus. Similar drawings and photographs of engine uncowled as well as a brief explanation of the engine tilting arrangement and mention of the water radiator. *Les Ailes*, July 20, 1939, page 8, 7 illus.

The Gotha Goes High. New height record for two-engine light airplanes was set up on July 5 when the Gotha Go. 150S (two 50-hp. Zuendapp engines) reached a height of 26,400 ft. (8048 meters), beating the previous international height record for light airplanes in Class C-3 (airplanes with engine of 2- to 4-liter capacity), held by Major Brazda of Brunn, in a Tatra monoplane with a height of 24,450 ft. The Go. 150S took 1 hr. 24 min. to reach its ceiling, the height of 7000 m. being reached in 1 min. Machine had been modified slightly from the standard Go. 150 and was flown without cowlings, fairings, or cabin equipment and with oxygen apparatus. This is the first time that engines of such low horsepower have exceeded 26,000 ft. Brief note. *Aeroplane*, August 2, 1939, page 170, 1 illus.

The Heinkel He 115 Flying Boat. The Heinkel He 115 which, during a long-distance flight, crashed over the South Atlantic, was a three-place torpedo and general-purpose seaplane of all-metal construction of dural. Two B.M.W. 132-N 9-cylinder radial engines developing 850 hp. at 3400 meters. Wing span 22.2 meters. Weight empty 5305 kg. Total weight 9100 kg. of which a military load is 885 kg. Maximum speed 300 km./hr. near the ground, 335 km./hr. at 3400 meters. Cruising speed at 40 percent power at 3400 meters 295 km./hr. Climb to 2000 meters in 8.5 min., to 4000 meters in 18 min. Range at cruising speed 2100 km. Short note giving these and other details. *Les Ailes*, July 20, 1939, page 9.

GREAT BRITAIN

The Blackburn Skua. The Skua I is the first monoplane to be adopted for the Fleet Air Arm as well as the first two-seater fighter dive-bomber for the Navy, and is primarily designed for use in aircraft carriers. Way in which the wings may be folded, in spite of the difficulties imposed by combing it with the installation of a retractable undercarriage, is pointed out. To provide buoyancy in the event of forced descent onto the water, various water-tight compartments are provided in the wings and in the fuselage, and the cockpit itself is water-tight up to the coaming. The Skua can maintain a heavy fire on its target from fixed guns in the wings while diving to bomb it, and heavy bombs can be launched directly onto their target by the simple process of aiming the whole airplane at the target, and releasing the bomb in the dive. Speed is kept down to about 280 m.p.h. by special air brakes or diving flaps of a modified Zapp type which can be pulled down when diving at top speed. Even when flaps are lowered at very high flying speeds, there is little change of trim.

Bristol Perseus XII 9-cylinder aircooled sleeve-valve radial engine providing 830 hp. for take-off and rated at 745 hp. at 2400 r.p.m. at 650 ft. Wing span 46 ft. 2 in. As a two-seater fighter, weight empty 5490 lb.; oil (10 gal.) 90 lb.; maximum speed at 6500 ft. 225 m.p.h. and at sea level 204 m.p.h. As a drogue-target tower, weight empty 5490 lb., military load 1381 lb.; oil (6 gal.) 54 lb.; maximum speed 229 m.p.h., and at sea level 205 m.p.h. Maximum cruising speed at 15,000 ft. 189 m.p.h. No particulars as a dive bomber. Very long detailed description of design and construction, flying controls, power plant, hydraulic and pneumatic systems, characteristics and performances, and cross-sectional drawings showing location of equipment and structure, as well as many photographs. *Aeroplane*, August 9, 1939, pages 192–195, 174, 8 illus. Long detailed description with cutaway drawing showing location of equipment and structure of the wing. *Flight*, August 10, 1939, pages 125–131, 12 illus.

The Bristol Bombay Bomber-Transport. All-metal high-wing cantilever monoplane being produced in the Short and Harland Works at Belfast for the R.A.F., is powered by two Bristol Pegasus XII engines with Rotol three-bladed adjustable-pitch propellers. It is designed and equipped for alternative duties of troop carrying, bombing, or transporting either fuel, water or spare engines. Crew of four consists of pilot, navigator/radio operator, and two gunners. Three 180-gal. auxiliary tanks can be carried in the main fuselage as equipment for long-range flying, and can be refueled by pressure from outside or with assistance of an internal pump. Main portion of fuselage can be arranged to provide seating accommodations, luggage racks and breathing tubes for 24 fully-armed troops. Seating can be removed to provide for various bomb loads, ten stretchers, spare motors, three fuel tanks, or three water storage tanks. Dome of the hydraulically operated gun turret in the tail can be jettisoned by withdrawing two locking pins and pulling two handles. Span 95 ft. 9 in. Weight empty 13,800 lb. and loaded 20,000 lb. Maximum speed 192 m.p.h. at 6500 ft. Cruising speed 160 m.p.h. at 10,000 ft. Climb to 15,000 ft. 20 min. Maximum range at 160 m.p.h. 2230 miles. Very long description with cutaway drawing showing location of equipment and type of structure and with characteristics and performance. *Aeroplane*, August 2, 1939, pages 157–160, 8 illus. Long detailed description. *Flight*, August 3, 1939, pages 103–107, 12 illus., 1 table.

The Phillips and Powis Miles Master. "Most advanced and fastest of all the World's training aeroplanes, the Phillips and Powis Miles Master, with a 715 h.p. Rolls-Royce Kestrel XXX liquid-cooled motor, is now in full production. . . . . for the training of the Royal Air Force. . . . . The Miles Master is the fastest wooden aeroplane ever to go into production and the prototype is probably the fastest all-wood aeroplane ever built."

Miles Master two-seater tandem single-engine low-wing cantilever monoplane has retractable undercarriage and constant-speed propeller. Wing loading 25.4 lb./sq.ft. Maximum speed 250 m.p.h. at 15,000 ft. Cruising speed 216 m.p.h. at 15,000 ft. Time to climb to 5000 ft. 3 min. Landing speed 64 m.p.h. Service ceiling 28,000 ft. Cruising range 440 miles. Long detailed description of layout, construction, power plant, and accommodation, as well as characteristics and performance. *Aeroplane*, July 26, 1939, pages 128–132, 127, 12 illus.

Production at Belfast. Photographs of stages in production of Bristol Bombays in the Short and Harland Works at Belfast, and of the Handley-Page Hereford (two 1000-hp. Napier Dagger engines) as produced by the same company. *Aeroplane*, August 9, 1939, pages 190–191, 5 illus.

ITALY

Italy's New World Record. Italy has established a new world's record for distance in a closed circuit, subject to homologation by the F.A.I. Lt. Col. A. Tondi, Capt. R. Dagasso, Pilot F. Vignoli, and Sergeant A. Stagline covered a distance of 8040 miles in 56 hr. 30 min. at an average of 142.4 m.p.h. Three-motor monoplane was used, "which must almost certainly be the new Piaggio long-range monoplane with biplane flaps" described in the July 12 issue. The Italians also broke the speed record over 6214 miles at 147 m.p.h. Brief note. *Aeroplane*, August 9, 1939, page 175.

Bellanca Model 14-9. Model 14-9 full-cantilever low-wing three-seater monoplane. Ken Royce 5F 90-hp. engine. Wing span 34 ft. 2 in. Maximum speed 135 m.p.h. Cruising speed 120 m.p.h. at 3000 ft. Cruising range 420 miles. Long description. *Aero Digest*, August, 1939, page 137, 3 illus.

The Case for the Low-Wing Trainer. P. Wilcox. Advantages which the low-wing trainer has shown in every-day training use, and in particular the Ryan S-T sport trainer used at the Ryan School of Aeronautics. Reference is made to the YPT-16 purchased by the U.S. Army Air Corps for the primary training of cadet pilots. *U.S. Air Services*, August, 1939, pages 20–21, 1 illus.

Harlow PC-5 Trainer. New all-metal low-wing airplane primarily intended for military training has a fuselage slightly narrower and more elliptical than the PTC-2, and seats its occupants in tandem. Flaps are of the perforated split trailing-edge type electrically operated, and may be stopped in any position within the maximum of 45°. Warner Super Scarab 145-hp. engine. Wing span 35 ft. 9.75 in. Wing loading 12.31 lb./sq.ft. Maximum speed 170 m.p.h. Cruising speed 160 m.p.h. Landing speed 45 m.p.h. Rate of climb 850 ft./min. Service ceiling 16,500 ft. Cruising range 600 miles. Description. *Aero Digest*, August, 1939, page 133, 3 illus. Short description. *Western Flying*, August, 1939, page 28, 1 illus.

Rearwin "Cloudster." High-wing strut-braced two-seater monoplane available as the Model 8090 (90-hp. Ken-Royce 5F engine) and as the Model 8125 (120-hp. 7F Rearwin engine). Wing span 34 ft. 1.75 in. Wing loading 10.10 lb./sq. ft. for the first model and 11.125 lb./sq.ft. for the second model. Maximum speed for the second model 145 m.p.h. Cruising speed 125 m.p.h. Cruising range 675 miles for the Model 8090. Short description. *Aero Digest*, August, 1939, page 134, 1 illus.

Air Transportation

The Netherlands. J. F. Van Wickel. Listed high among the purchases of American aeronautical equipment, the Netherlands and the Netherlands Indies have bought more than $15,000,000 worth of our products during the past three years. One of the world's largest air-transport companies flies the Dutch flag, and the Netherlands has one of the finest air forces among the smaller powers. Development of the K.L.M. (Royal Dutch Airline), American equipment used, activities during 1938, air services operated, and other commercial activities are discussed. *Aero Digest*, August, 1939, pages 125–126, 128, 8 illus.

Pagham as an Empire Base. Requirements for an Empire flying-boat base, and suitability of Pagham harbor for such a base. *Aeroplane*, July 26, 1939, pages 133–134, 1 illus.

Balloons

"Balloon Barrage Strategy." The balloon barrage or minefield of the air, when hoisted in clear air, does not approximate to a minefield, but to a barbed wire entanglement, and it will be regarded by an enemy as an impediment which can be destroyed before or in the early stages of an attack. An enemy who intends to bomb from a great height might be grateful for the target indication provided by visible balloons, as he is thereby enabled to bomb from above them at leisure and with deliberation. It would seem then that there is no advantage to be gained by flying the barrage in clear air.

Concealment of balloon barrages, either partial or complete, is discussed. If two bombers strike two attachment cables, there will probably be a loss on the one side of two bombers, and the other of two balloons freed from the screen. If six bombers strike six attachment cables, then there would be a loss of six bombers on one side and a complete screen on the other. Advantages of the German balloon barrage scheme over that of the British are pointed out. The Germans use a much greater number of smaller balloons, which are more manageable and can more quickly be hoisted or lowered. They replace these balloons by kites if the weather is unsuitable for balloons. Balloons and kites do not support a screen after the British fashion, but rather a number of wires attached to winches on the ground. The correct use for the balloon barrage would appear to be in conjunction with fighters, guns, sound locators, and searchlights. *Aeroplane*, August 9, 1939, page 176.

Miscellaneous

The 27th Session of the I.C.A.N. Short account of meeting of the International Commission for Air Navigation at Copenhagen, June 6 to 12. *Aeroplane*, July 26, 1939, page 134.

The Frankfurt International Meeting. C. G. Grey. An account of the international meeting of sports pilots from July 27 to 31 and the annual race meeting on July 30, and a brief account of a visit to the national gliding contest at the Wasserkuppe. Motor cars and trailers used for seaplane transport are referred to with photographs. *Aeroplane*, August 9, 1939, pages 185–189, 10 illus.

Aircraft Instruments and Navigation

Kollsman Direction Indicator. Kollsman Type 488B direction indicator, intended primarily for mounting in a horizontal position, employs a moving pointer which continuously shows the direction against a fixed dial. Brief note. *Aero Digest*, August 9, 1939, page 150, 1 illus.

Aeronautical Charts. New and revised editions of aeronautical charts now available from the U.S. Coast and Geodetic Survey, including 21-DF radio direction finding chart, regional charts, and sectional charts. Brief note. *Aero Digest*, August, 1939, page 105.

Airport Equipment

Diesel Electric Sets for Emergency Power. Caterpillar Model 34-15 and 44-20 completely self-contained Diesel-electric sets for small airports are of 15- and 20-kw. capacity. They are designed to be operated by personnel without special training. No special bases, rheostats, switchboards, or instruments are needed. Both models are supplied in three-phase, 110-, 220- or 440-volt types, as well as single-phase 110-220 volt three-wire types. *Aero Digest*, August 9, 1939, pages 149–150.

Portable Lighting System for Airports. Trippe portable airport-runway lighting system comprises 20 two-reflector lights powerful enough to illuminate a field 1000 ft. long and 200 ft. wide. Individual lights are staggered 100 ft. apart on both sides of a 1000-ft. field. Each light is powered with its own storage battery, and throws out a V-shaped beam. Brief note. *Aero Digest*, August 9, 1939, page 150, 2 illus.

Pre-Fabricated Steel Hangars. Blaw-Knox predesigned steel hangars may be obtained complete and erected by the purchaser or by the company's special erection service. Standard line will include single-span widths up to 100 ft., but larger sizes will be available. Construction includes lead flashing under the roof ridge cap to insure weather tightness, interlocking caps through the roof and wall sheet to allow for expansion and contraction. Underside of joint channel is crimped to eliminate capillary attraction, to ventilate the joint, and to raise the flow point, thereby reducing corrosion possibilities. Brief note. *Aero Digest*, August 9, 1939, page 149.

Ice Elimination Equipment

Icing Viewed by a Chemist. J. Wiser. The possibility that an electrostatic charge is produced on the metal airplane due to the exhaust gases is mentioned, and chemical phenomena in the formation of ice on an airplane are explained to account for the violence of the phenomena of icing in regions where the possibility of formation is unsuspected. If the point of impact of the wing could be considered the catalyzer of icing, this formation could be hindered by replacing the fixed point of impact by a movable point during the period of the danger of icing. One suggestion consists of placing along the leading edge of the wing small sharp-angled cones arranged at short distances apart and rotated by the flow of air. Their rotation would produce a deflection of the water in surfusion which would prevent the phenomenon of icing.

Various methods of eliminating ice formation on the wings of aircraft are briefly reviewed including the Goodyear system, the process used by British commercial aircraft, and heating of the wing. *Les Ailes*, July 20, 1939, page 8, 1 illus.

Aerial Photography and Mapping

Some Recent Developments in British Surveying Instruments. Major-General M. N. MacLeod. Recent developments of the ground surveyor's principal instrument, the theodolite, and of air photographic-surveying instruments are discussed from the optical standpoint. The F.24 standard British service air camera, the seven-lens camera developed at the Royal Aircraft establishment, the Z.D.15 stereoscope, the Thompson comparator, and automatic plotting machines (including two experimental stereogoniometers based on Fourcade's design made for the British War Office) are discussed. References are made to work of the British Air Survey Committee. Physical Society paper. *Engineering*, August 4, 1939, pages 149–151, 7 illus.

Testing Apparatus

Instantaneous Fluid-Pressure Recording Equipment. S. E. Goodall and R. B. Smith. Pressure to be measured produces small capacity changes in a pressure unit, which are translated into large current changes in an oscillograph element. Unit to which the pressure is applied is a small air condenser which forms one arm of a four-arm bridge to which high-frequency voltage is applied. Output of bridge is a modulated high-frequency voltage, modulation being proportional to the change of capacity of the pressure unit for small variations. This signal is amplified and rectified thereby producing a unidirectional current proportional to fluid pressure which operates one element of an oscillograph. Apparatus can be used for measurement of pressure surges in almost any type of apparatus, but was developed to record the pressure developed in tanks and arc-control chambers of high-voltage switchgear when tested under short-circuit conditions. Long detailed description of apparatus, and an estimation of gas-bubble size. *Engineering*, August 4, 1939, pages 127–129, 9 illus., equations.

Materials

Automotive Materials—New Developments. Pigmented version of G.E. Glyptal 1294 Clear to prevent adhesion of weld spatter when applied to parts before welding. "Baking Platelustre" reproducing colors of many metals. "Triple Casting" method of producing piston rings. Short notes on these new developments. *Automotive Industries*, June 15, 1939, pages 702, 738.

British Standard Specifications. Revised specifications for liquid and jelly gelatin glues for aircraft purposes are mentioned in a very brief note listing principal modifications. Specifications for hexagonal headed bolts (high-tensile steel) and hexagonal brass nuts are referred to in another short note. *Aircraft Engineering.*, July, 1939, pages 279, 290.

Metals

What Is New in Heat-Treating Methods, Materials, Processes. E. F. Davis. Control of grain size as facilitating development of new steels and modifications in heat-treating processes; modern progress in the steel mill; employment of the Carbometer and Turbidimeter; lime-silica ratio; newer deoxidizers employed to aid steel quality; the internally heated immersion bath in salt-bath hardening; dry cyaniding with ammonia gas as eventually obsoleting cyanides and activated baths; gas carburizing as gradually supplanting box carburizing; large heat-treating units for carburizing quench washing and tempering mechanically; a gas carburizing furnace which eliminates use of a muffle; principle of tube combustion or radiant heating which is being used extensively in atmosphere-controlled furnaces for sheet and strip annealing, furnaces for short-cycle malleable annealing, and other heat-treating applications; and the present status and future possibilities of induction hardening. *S.A.E. Jour. (Trans.)*, August, 1939, pages 351–356, 3 illus.

Corrosion and Protective Coatings

The Corrosion of Metals. O. P. Watts. Faraday's law on corrosion is considered and four types of corrosion are derived from it. Discussion covers: the electrochemical series; discharge potential of hydrogen; applications of the electrochemical series; corrosion by reduction in valence of a metal already in the electrolyte; corrosion by displacement of a metal; corrosion by visible displacement of hydrogen gas; inhibitors; the magical effect of amalgamating zinc; arsenic inhibiting corrosion of a pipe line to a copper blast furnace; and passivity. To be continued. From Bulletin of the University of Wisconsin. *Engineer*, August 11, 1939, pages 166–168, 1 table.

Corrosion Resistance of Aluminum Cylinder Heads. L. W. Kempf and M. W. Daugherty. Major forces in the corrosion of aluminum-alloy cylinder heads is the composition of the cooling water, according to the investigations described. High chloride concentrations are relatively much more corrosive than abnormally high concentrations of other salts commonly occurring in natural waters. Amounts of chloride large enough to cause objectionable corrosion of aluminum cylinder heads are often present in automobile cooling systems when the cars leave the factory, and the source may be soldering flux or sal ammoniac used for sealing porous castings. Erosion caused by direct impingement of water of high velocity on exposed aluminum surfaces also is a major factor in the problem. Elimination of erosion by adequate gasket design is apparently easily achieved. Even in the presence of both causes corrosion can be greatly reduced, if not practically eliminated, by using soluble oil as a corrosion inhibitor. Cylinder-head alloy and temper and gasket material are relatively insignificant factors in the corrosion of aluminum cylinder heads. *Automotive Industries*, August 15, 1939, pages 156–159, 169, 6 illus.

Iron and Steel

The Valve Spring as a Metallurgical Problem. M. Bonzel. A chromium-manganese-silicon steel was selected by the author's firm as it seemed to combine the maximum advantages for the manufacture of valve springs. Optimum quenching temperature was in good accord with the dilatrometric diagram and fatigue limit passed through a maximum for a drawing temperature of 840–875°F. Such drawing restores the elongation to a notable extent without appreciably diminishing tensile strength and elastic limit. Warping during quench was investigated also.

Results obtained by M. Piquet on a silico-manganese steel without chromium as well as those found by M. Cazaud on a chromium-molybdenum-silicon steel are discussed and compared with those obtained by the author's firm. A special machine developed by Etablissements Bohin for endurance tests of wires for valve springs is described. This machine takes specimens without special machining of the ends permitting the study of important effects of surface condition. *Automotive Industries*, August 15, 1939, pages 150–155, 7 illus.

Grain Size of Steel. N. F. Ward and J. E. Dorn. Abnormality and hardenability, their relation to heat-treating practice, and effects of austenitic grain size on service properties of variously heat-treated steels. Abnormality among pack-carburized steels, relation of grain size to quench-cracking susceptibility, and adaptability of hardenability information to plant control are also covered. Continued. *Metals and Alloys*, July, 1939, pages 212–218, 6 illus., 2 tables.

Non-Ferrous Alloys

Anodic Coating of Aluminum—Behavior of Alloy Constituents. F. Keller, G. W. Wilcox, M. Tosterud and C. J. Slunder. Fundamental facts regarding the oxidation characteristics of various micro-constituents of aluminum alloys revealed by the described investigation, may be employed to explain variations in results obtained in the anodic oxidation of commercial aluminum alloys. Different constituents evidently have different oxidation characteristics and these characteristics determine to some degree the results obtained when various types of aluminum alloys are treated by the anodic oxidation process. Electrolytic oxidation characteristics were determined on a special group of samples made from high-purity aluminum (99.95 per cent Al) and high-purity alloying metals. *Metals & Alloys*, July, 1939, pages 219–225, 38 illus., 1 table.

Japanese Claim New Alloy for Aircraft. Two members of the Tokyo Imperial University's Aeromechanical Research Institute claim to have compounded a new light alloy metal called "extra-superduralumin," or "S.S.B." The new metal is compounded of aluminum, copper, zinc, manganese, magnesium, and other metals, and is declared to be immune from all climatic conditions. Compared with the British R.R. 77 which has a tensile strength of 45 kilos, S.S.B. is said to have a tensile strength of 53 kilos. Brief note. *Automotive Industries*, August 15, 1939, page 185.

Magnesium and Its Alloys—Recent Developments in Great Britain. J. L. Haughton. Research on the effects of the addition of new elements to magnesium and of the different methods of working these alloys is being undertaken and an investigation is being made of the constitution of a number of these alloys (mostly binary) in order to assist in the study of chemical properties. The small amount of work which has been done on the alloys for use at high temperatures is discussed. Increased production of metal and use of alloys, lines of research, and measures being taken toward improvement of mechanical properties are reviewed, and some results obtained in the National Physical Laboratory's investigations described. *Industrial and Engineering Chemistry, Ind. Ed.*, August, 1939, pages 969–971, 3 illus., 2 tables.

The Melting of Light Alloys. A. J. Murphy, S. A. E. Wells and R. J. M. Payne. Grain size and methods of controlling it. Grain refining additions, stability of alloys containing niobium, difference in melting technique between aluminum and magnesium alloys, and grain size of metal charged are discussed. Concluded. International Foundry Congress paper. *Metal Industry*, July 14, 1939, pages 33–35, 5 illus., 1 table.

The National Physical Laboratory. To meet the increasing demand for simple and rapid, yet accurate, methods of calibrating the extensometers used for measuring elongations and strains in testing materials, the Engineering Department has developed a calibrating apparatus comprising means for operating the extensometer positively through distances accurately controlled by slip gages. Extensometer is assembled upon a divided rod of which the upper part is rigidly attached to a massive frame, while the lower portion can move relative to the part in an axial direction and is screwed into a larger diameter rod or plunger lapped to fit in the frame base. Description of this equipment as well as a review of research being carried out on fatigue properties of materials, lifting gear, damping capacity, fretting corrosion, calibration of other testing machines, creep, and pipe flanges. To be continued. *Engineering*, August 4, 1939, pages 143–145, 2 illus., 2 equations.

Pin Hole Detector. G. A. Caldwell. A 0.015-in. hole in flat-rolled products can be detected at speeds of 100 to 1000 ft./min. by means of the device described which is a special kind of Phototroller designed to meet a specific set of conditions. Hole detector consists of a light source, phototube housing, and control unit, while the marker consists of control unit, operating solenoid and tachometer generator. Detector may be used in conjunction with a hole marker only, with a hole marker and standard classifier, or with a classifier having an additional pocket besides those for under- and over-gages, and into which pocket the pieces with holes are discharged. Description of detector and marker. *Iron Age*, June 29, 1939, pages 26–28, 4 illus.

Fundamental Nature of Welding. D. E. Babcock. Effects of heating velocities, carbide diffusion, and carbide melting in electric spot, flash, and resistance welding. Among these processes, there should be certain very fundamental chemical and metallurgical effects which could be readily interpreted or predicted from the equilibrium data, if the proper application of diffusion kinetics were applied to the welding process in conjunction with chemical equilibrium restrictions. Time element is of major importance. The equilibrium diagram for the carbon-iron alloys is shown and discussed

to clarify the explanation of melting as it occurs during welding. The condition which arises from the extrusion of the carbide-rich liquids into the cooler portions of the metal matrix is discussed. On purely theoretical principles it is pointed out that the weld line structure illustrated is ferritic and low in carbon content, a conclusion arrived at by both metallographic studies and corrosion properties. Chemical proof of weld composition is given. *Welding Jour.*, August, 1939, pages 477–479, 3 illus., 1 table.

Notes on Welding Practice. J. G. Waterworth and A. R. Mowbray. Quality of the metal introduced by application of the filler rod in welding; analysis to determine the efficacy of the filler rod; inclusion of silicon for prevention of splashing; content of sulphur and phosphorus; employment of a copper-coated rod which possesses the added factor of assisting in prevention of oxidation; importance of the airframe being devoid of all redundant members, each being curtailed to the bare minimum and as narrow and short as possible; minimizing the length of the weld at intersecting tubes by keeping the tubes at as near a 45° angle as possible; necessity for making the tack welding as few as possible; starting the work inside the angle; and final welding procedure. Typical welded fuselage structure and details of the joints are illustrated in drawings. *Aircraft Engineering*, July, 1939, pages 290–291, 7 illus.

Rubber

Adhesion of Neoprene to Metal. F. L. Yerzley. The A.S.T.M. standard procedure (D429–36T) was examined critically as a possible means of evaluating adhesion to metal, but was found lacking in respect to control of both pressure on the vulcanizate and flow in the mold. Modifications of the A.S.T.M. standard adhesion test are introduced as a means of controlling both pressure and flow during vulcanization of test specimens. By use of a relatively thin layer of vulcanizate, nominally ¼ in. thick, it is shown that a yield point develops in the load-elongation curve revealing internal failure of test specimens in many cases well before their ultimate strength is recorded. Adhesion of Neoprene Type E to brass is used as a means of evaluating the test and of demonstrating factors of commercial importance.

Procedure is developed for use of chlorinated rubber as a Neoprene-to-metal adhesive, and it is shown to be applicable to steel, 18–8 stainless steel, copper and aluminum. Best adhesion obtainable between Neoprene and metal by use of chlorinated rubber is equivalent in strength to adhesion to brass. *Industrial and Engineering Chemistry, Ind. Ed.*, August, 1939, pages 950–956, 12 illus., 8 tables.

Recent Developments with Koroseal. F. K. Schoenfeld, A. W. Browne, Jr., and S. L. Brous. Koroseal plastics exhibit a wide range of physical, chemical, and electrical properties which can be modified by the use of suitable plasticizers, loading pigments, and special compounding ingredients. Essentially rubberlike Koroseal stocks may be milled, calendered, extruded, and molded without vulcanization into a variety of enduring products. Koroseal is especially valuable for uses requiring resistance to water, acids, alkalies, oxidizing agents, and corrosive chemicals. Physical, electrical, and chemical properties and applications are discussed. *Industrial and Engineering Chemistry, Ind. Ed.*, August, 1939, pages 964–968, 12 illus., 5 tables.

Synthetic Rubber-Like Materials. H. E. Blank, Jr. Properties of synthetic-rubber materials which are constantly being introduced to new functions in the automotive field, and their suitability for these various applications, including: Thiokol; "Resistoflex" PVA, a flexible synthetic resin basically polyvinyl alcohol; Koroseal; Neoprene in both automotive and aircraft applications (Mareng fuel cell); and Perbunan. Long discussion. *Automotive Industries*, June 15, 1939, pages 696–702, 719–721, 15 illus.

Meteorology

A Large-Scale Upper-Air Stream Chart. G. Schinze and R. Siegel. Means of accurately computing winds aloft over regions where no balloon soundings are taken or where low clouds prevent the soundings. It cannot completely replace the method developed by Vernon, or its adaptation by George and Elliott, for computing winds aloft over land areas, because its accuracy is least over land, and it becomes practically zero over mountainous districts. Sea-level pressure in millibars less than 1000 is added to the surface temperature expressed in degrees Centigrade. This value (Se) is nondimensional, but it is possible to choose a pressure surface so that isolines of Se value become directly proportional to the geopotential of the chosen surface. This proves to be the 756.8 mb. surface. Isolines of Se drawn in this way can be considered from a practical standpoint as describing the same wind relationship as do the more familiar isobars, although to a different scale. Method is worked out. Conditions when the limit of variation of Δt (surface temperature − mean virtual temperature of the layer) at 3.8°C. for a change of 10 Se over the same area, is not likely to be exceeded are pointed out. Criticisms of the method given by R. Scherhag (*Ann. der Hyd.*, June, 1939) are added. Translated from *Die Grossraumige Hohenstromungskarte*," from "Archiv der Deutschen Seewarte," Volume 58, No. 2, 1938. *Am. Meteorological Soc., Bul.*, June, 1939, pages 258–262.

Outline of Physics of the Clouds. "Micro-physics of the Clouds," W. Findeisen; "Macro-physics of the Clouds," W. Peppler; "Physical Synoptics of Clouds," T. Bergeron; translated from German by K. O. Lange and C. F. Brooks. Outline of the first paper covers: water clouds, condensation nuclei, process of condensation, description of elements of condensation, water vapor in water clouds, coalescence of drops, falling out of drops, and optical and acoustic phenomena in water clouds; ice clouds, sublimation nuclei, process and elements of sublimation, water vapor in ice clouds, coalescence of ice crystals, settling out of ice crystals, and optical phenomena; and clouds with elements in both frozen and liquid state, simultaneous existence of condensation and sublimation nuclei, circumstances for condensation and sublimation when both kinds of nuclei exist, crystallization of droplets, formation of water and ice clouds one over the other or side by side, and existence of water drops and ice crystals in the same place.

"Macro-physics of the Clouds" deals with simple stratiform clouds, forms of multiple layers, simple cumuliform clouds, stratiform clouds developed from cumuliform clouds, clouds composed jointly of heaped and sheet clouds, and special cloud forms. "Physical Synoptics of Clouds" is devoted to clouds of the tropospheric air masses, clouds of the tropospheric frontal regions or fronts, stratosphere clouds, effects of orography and friction on clouds, and 14 weather zones of a hemisphere or geographical distribution of clouds. Very short statements are given in this outline. *Am. Meteorological Soc., Bul.*, June, 1939, pages 235–247.

Stratospheric. An altitude "record" is claimed to have been established by one of the radio sounding balloons of the Danish Weather Service. Sent up from Aalborg, Jutland, the instruments recorded a height of approximately 82,000 ft. Lowest temperature was recorded at an altitude of 31,200 ft., −48.8°C. below zero. At 82,000 ft. the temperature was about 17° higher, or −32°C. Brief note. *Flight*, August 3, 1939, page 110.

Fuels and Lubricants

Automotive Materials—New Developments. Elektrion R addition agent, supplied by Société des Huiles De Cavel & Roegiers, Belgium, improves the engine oil to which it is added in regard to its viscosity index. It is produced from mineral oils by treatment with electric glow discharges, which appear to effect chemical and physical changes in the oil. Elektrion R lowers the A.S.T.M. pour point of practically any oil to which it may be added, and increases the "oiliness." Oil molecules are said to undergo a change during the electronic treatment which considerably increases the bulk of the oil, and particles of the oil after treatment have a high physicochemical activity, as indicated by the fact that they clog water particles. Owing to the higher "oiliness," wear will be reduced on parts of a bearing surface on which the lubricant film may be reduced to molecular thickness for any reason. Elektrion R oil is said to dissolve the oxidation products of the oil and also to be a solvent for low-temperature oxidation products of motor fuels. Effect of Elektrion R oil additions on the viscosity index of several mineral oils is illustrated in a graph. *Automotive Industries*, August 15, 1939, pages 155, 190, 1 illus.

Engine Design and Research

Aircraft, Diesel, and European Engines. Abstracts of papers presented at the S.A.E. World Automotive Engineering Congress (previously abstracted from preprints), dealing with high-output European engines, lubrication of aircraft engines, aircraft propeller vibration problems, and malleable iron in automotive production. *Automotive Industries*, June 15, 1939, pages 712–715, 3 illus.

The Design of Aeroplane Ducts. G. N. Patterson. Rules to be followed in the design of the entry and general external shape of airplane ducts for the reduction of internal and external drag. Internal drag of a duct system, quantity of flow, duct losses, corner and diffuser designs, duct entries, external drag, and analysis of duct drag and leak drag are discussed in detail. *Aircraft Engineering*, July, 1939, pages 263–268, 15 illus., 2 tables, 6 equations.

Detonation in Otto-Cycle Engines. H. Weinhart. Type of combustion of the remainder of the charge, which causes knocking, was measured once more, as literature on this subject provided no detailed results. Tests were made to decide whether a deeper understanding of the mechanism of the combustion process could be obtained by use of electrical apparatus. Tests were first carried out in a cylindrical tube, and then, with the same apparatus, in the engine. Three different measurements were taken but no definite deductions were obtained from the pressure measurements. An ionization method using a cathode-ray oscillograph was adopted, not to determine the instant of arrival of the flame front, but, from variation in the ionization stream, to detect chemical and thermal changes in the charge.

In a knocking engine, ionization stream is essentially different from that of a detonating gas mixture, as shown by measurements, so that it is certain that no detonation wave occurs in a knocking engine. As temperature and mixture formation are not consistent throughout the combustion chamber, instant of the initial ignition and its location are dependent on circumstances, and "centers of ignition" are produced, from which combustion progresses. Observed negative flame velocities and their great dispersion are easily explained by these "centers of ignition." An almost completely closed flame-front, such as is present with normal combustion, is therefore not present in the remainder of charge where knocking is produced.

Effects of antiknocking media might be largely explained by indications that these delay the first reaction, or retard from inception the rate of chemical change and so give more opportunity to the flame-front to penetrate throughout the remainder of charge before it is ignited by pressure rise. As, at the instant of occurrence of the first ignition centers, the whole of the remainder of the charge is ready for combustion, the latter spreads extraordinarily quickly and so a region of high pressure is produced in which flow is away from spark plugs and, also, where combustion is retarded by cooling. Since such a pressure disturbance increases during its advance, it may be imagined that this, when meeting a rigid wall, causes noise of knocking in same way as a detonation wave. Performance drop is due, then, to increased transference of heat to wall, caused by movement of gas masses produced by momentarily increased pressure at reflection of gas oscillations and consequent turbulence. Short abstract. *Aircraft Engineering*, July, 1939, pages 282–283. *Luftfahrtforschung*, February 20, 1939, pages 74–83, 13 illus.

Measurements of the Flow Speed in Cylinders of Externally Driven B.M.W.-VI Aircraft Engines. H. Wenger. Velocity of air into the cylinder of a water-cooled BMW-VI aircraft engine was measured by means of a hot filament anemometer. This measurement was possible even if velocity and temperature of the air varied widely and suddenly, during the course of the cycle. Mean velocity of the air past the hot filament was measured over its length. Special installation made it possible to take measurements with the wire element at various points in the cylinder, the recording element being connected in series with an oscillograph circuit to a source of current. Investigations were carried out on a separately driven single cylinder, using a B.M.W.-VI cylinder on a test bed, in order to determine the influence of the r.p.m., throttle opening, cooling-water temperature, and compression ratio on the magnitude of the air velocities in the cylinder. Curve of air velocities during the complete cycle showed similar characteristics in all exposures. Motion reached its maximum during induction stroke, diminished during compression, and increased again during expansion and exhaust. To obtain a criterion of the influence of the r.p.m. and throttle position, mean air velocities for the individual strokes, and for the whole cycle, are shown in separate diagrams in the original article. Short abstract. *Aircraft Engineering*, July, 1939, page 282. *Luftfahrtforschung*, February 20, 1939, pages 62–73, 12 illus., 1 table, 30 equations.

Simple Approximate Determination of Cycle Efficiency in Otto-Cycle Engines from the Viewpoint of Variability of Specific Heat. O. Lutz. For the degree of cycle efficiency of Otto engines, the influence of the variability of specific heat with temperature can be represented with good approximation by use of the formula $\eta = 1 - 1/\varepsilon^{m-1}$, if m is chosen equal to the adiabatic coefficient for the expansion process. Since compression ratio exerts only a slight influence, and calorific value of the mixture exerts a marked influence on this figure, the formula may be used as a good approximation for the influence of compression ratio. By variation of the calorific value of the mixture m may be altered according to an empirical formula. Relationships illustrated could be adapted to provide detailed summaries of future calculations of cyclic efficiencies with regard to specific heats, and to reduce their results to a simplified form for practical application. Report of the Herman Goering Aeronautical Research Institute, Braunschweig. Short abstract. *Aircraft Engineering*, July, 1939, page 282. *Luftfahrtforschung*, February 20, 1939, pages 59–61, 3 illus., 2 tables, 31 equations.

A Symposium on Varnish in Engines. F. F. Kishline. Offending "varnish" is defined as a "synthetic resinous compound precipitated by little-known chemical reactions, oxidation, exposure of oil to relatively high tem-

peratures, presence of foreign materials, or various combinations of these causes. Time and temperature appear to be principal items in an engine which govern the condition, and temperature may or may not be the sump temperature. Possibly there is a critical temperature above or below which formation is slight, although one of the experiences contributed indicated varnish formation at temperatures up to 400°F. Experience, opinions, and questions of many anonymous S.A.E. members and their companies on the subject are presented. Sludge and varnish work at Chevrolet, clogging of oil-control rings, and effect of type of lubricating oil are covered in the discussion following the paper. *S.A.E. Jour.* (*Trans.*), August, 1939, pages 322–324, 334.

Engine Manufacture

Quantity Plus Quality. C. G. Grey. History of the Rolls-Royce company before and after its entry into the aircraft-engine field is traced, and the new Rolls-Royce factory at Crewe is described in detail including: machine tools; subassemblies; training school; super-inspection; and gages. *Aeroplane*, July 26, 1939, pages 119–125, 18 illus.

Parts and Accessories

A Non-Icing Fully Maneuverable Aircraft Carburetor. M. J. Kittler. Neither severe military maneuvers, such as power dives and inverted flight, nor icing conditions will affect appreciably the operation of the Holley aircraft carburetor. Fuel level is controlled by a double-diaphragm mechanism instead of by the conventional float mechanism, and in place of the fixed venturi and butterfly throttle construction is a variable-venturi mechanism which forms both the throttles and venturi. Metering is governed by a tapered needle valve actuated by a cam linked to the venturi throttles so that both air and fuel passages of the carburetor expand simultaneously as the venturi throttles are opened.

Causes of carburetor icing, requirements for a carburetor to function properly in all maneuvers, and metering characteristics are considered. Development of the carburetor since 1935, and the design finally developed and its operation are described in detail. Effect of fuel boiling in the jet is discussed by F. C. Mock. *S.A.E. Jour.* (*Trans.*), August, 1939, pages 357–363, 12 illus.

Aircraft Radio

A 500-Cycle Blind Landing System. E. N. Dingley, Jr. In the system recently installed and successfully tested at Lakehurst by the Navy Department, the cables are joined at their far ends by a shunting conductor. One cable is used for the outbound circuit while the other is used for the return circuit, constituting a large horizontal loop.

In the aircraft, two collector loops are mounted with their planes at right angles to each other and with the plane of each loop lying at 45° to the horizontal. When the aircraft is in horizontal flight directly above the midline between the two cables and at an altitude equal to half the distance between the two cables, the plane of each collector loop of the aircraft intersects one ground cable and at the same time is perpendicular to a plane intersecting the other cable. Each collector loop receives an optimum signal from one ground cable and no signal from the other. Output terminals of each loop in the aircraft are connected to individual audio amplifiers, each tuned to 500 cycles, and the output of each amplifier is connected to a rectifier type a.c. voltmeter having a range of 0–5 volts. Long description of system. *Aviation*, July, 1939, pages 60–61, 92, 6 illus.

Air Traffic Control. H. W. Roberts. Airport traffic congestion as the bottleneck, control of airway traffic and airport traffic, radio, communications procedure and its relation to airway traffic control, growth of air traffic, and radio for all aircraft are considered. *Aero Digest*, August, 1939, pages 129–130, 146, 3 illus.

Aeronautical Industry and Production

Dealing with the Problem of Personnel. C. S. Mattoon. Acute labor shortage in the aircraft industry, despite the efforts of manufacturers to bolster personnel, has developed solely because an aircraft organization requires in its man power a high standard of skill and experience as well as an industrial outlook rarely demanded elsewhere. Personnel Director of the Curtiss Aeroplane Division comments on the problems in the selection and training of personnel in aircraft manufacture, and present trends. *Aero Digest*, August, 1939, pages 121–122, 128, 4 illus.

Foreign News in Brief—Japan. Twenty-three manufacturing concerns in Japan are making aircraft, parts, and accessories. These companies claim to be manufacturing 25 different types of commercial aircraft ranging from the twin-engined 880-hp. Kotobuki, to the single-engine 28-hp. Tachikawa T.S.1. Of the 41 regular commercial airports and nine military airports occasionally used by civil aircraft, 33 have facilities for land planes only, 14 for land and seaplanes, and three for seaplanes alone. At the end of 1938 there were 22 civil aviation routes in regular operation. Brief note. *Aero Digest*, August, 1939, page 98.

Lockheed in High Gear. Production at the Lockheed plant during June slipped smoothly into high gear as five of the 14B twin-engined bomber transports rolled out of the factory every four days, and this rate was expected to hit three planes every two days before midsummer. More than 7000 employees are on the payroll compared with less than 3000 at the start of the year. Two large resistance welding machines, said to be the largest in size and capacity in any aircraft factory, are to be installed. They are capable of welding two sheets of aluminum alloy ½-in. thick, and have a throat depth of 50 in. Short note. *Aviation*, July, 1939, page 75.

Book Reviews

Wind, Sand and Stars, by Antoine de Saint Exupéry, translated from the French by Lewis Galantière; Reynal and Hitchcock, New York, 1939; 306 pages.

Like Anne Morrow Lindbergh's books, *Wind, Sand and Stars* is of interest not only to aviation enthusiasts, but to all who appreciate fine writing. The author, a member of the 1939 survey flights for the French transatlantic service, has been actively concerned with French aviation for 13 years. His first book, *Night Flight*, was widely acclaimed, and his present effort has been a best-seller since publication.

The book begins with his experiences as a student pilot in 1926. In the course of the narrative he deals not only with his experiences and adventures, but also with the men who worked with him, and the philosophy he evolved. His tribute to the courage of his friend and comrade Guillaumet is one of the most moving we have had the privilege to read. The account of his dramatic experiences when lost on the Sahara Desert is absorbing—the finest kind of an adventure story.

Combining as it does, aviation and literature, this book should enjoy wide circulation among aviation enthusiasts as well as the general public.

Soaring Wings, by George Palmer Putnam; Harcourt Brace and Company, New York, 1939; 294 pages, $2.50.

Amelia Earhart combined many qualities other than that of being a great pilot. Her husband in this biography interprets her philosophy of life, as well as her career, as no one else could. Her intense belief in the increasing participation of women in world affairs is, of course, the thread which goes through every chapter. Any critical comment on some of the activities of one who sacrificed her life in the great effort which was to climax her flying achievements, or discussion of the taste in revealing certain incidents in her life, would be out of place. A. E. will always remain in the forefront of the great proponents of aviation.

Such books as *Soaring Wings* will serve their purpose in stimulating others who try to climb by their own efforts to fame if not to fortune. There cannot be too many inspirational books of this kind written in a period when discouragement and fear for the future confront many young people.

Romantic Stories of Air Heroes, by Captain A. O. Pollard; Hutchinson and Company, Ltd., London, 1937; 300 pages.

Captain Pollard has written a fascinating story of the heroes of aviation from the pioneers of flight to the present day. After giving the history of the early French balloonists, Lilienthal, the Wright Brothers, Santos-Dumont, and A. V. Roe he devotes the remainder of the book to flights of men who may be called the precursers of air transport.

Bleriot, Hawker, Alcock and Brown, Major G. H. Scott, Sir Alan Cobham, Byrd, Lindbergh, and Kingsford-Smith are some of those who are given separate chapters. For any young man who wishes to review the developments of flight as laying a foundation for air transport of today this book will give him some idea of the courage and determination that were required to overcome the many obstacles encountered in flying over uncharted country.

Knots, Splices, and Fancy Work, by C. L. Spencer; Brown, Son and Ferguson, Ltd., Glasgow, 1939; 193 pages, 6s 6d.

While this book is intended primarily for seamen, it will be of interest to seaplane operators for the mooring of aircraft. Just as a study of the many uses of rope, it is encyclopedic as well as entertaining.

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The B. G. Corporation
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Thompson Products
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VIBRATION DAMPERS
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1939-1940

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Only the highest scientific degrees of members are given. Many of our members are entitled to use abbreviations after their names indicating honors, membership, and rank in national, scientific, and engineering organizations. These are omitted, except those indicating membership in the Royal Aeronautical Society.

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FOR ALPHABETICAL LIST SEE PAGE 30

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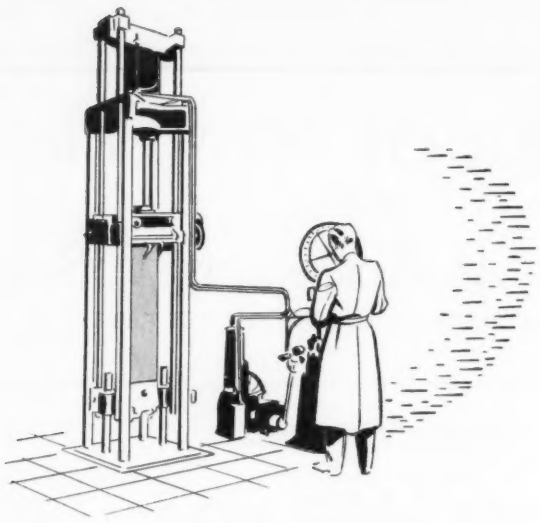
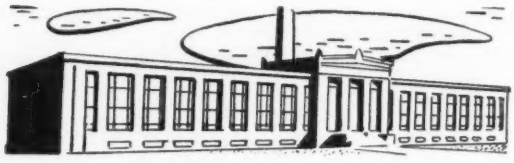


and why is this research, anyway?

If you should tomorrow be given the job of improving speed, or safety, or payload ratio of a 'plane, one of your first thoughts would inevitably be, "Why not use stronger, lighter materials?" Following this logic, you might inquire, "What materials are light and strong? How can we make them stronger and lighter?" Persevering, you would soon learn that what you want is largely an increase in the knowledge of materials, and you would find a



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Benefits from this program are visible. On the desks of aircraft designers you will find the reliable data developed in this way. In plants where 'planes are built you may see workmen applying important techniques so fostered. Study the maintenance methods of any major airline, and you will discover how knowledge contributed by research has made Aluminum equipment serve long and safely.

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Milch, Erhard, F.I.Ae.S.; State Secretary, Air Ministry; Inspector General, Air Corps; Vice-Pres., Deutsche Akademie der Luftfahrtforschung. Germany.

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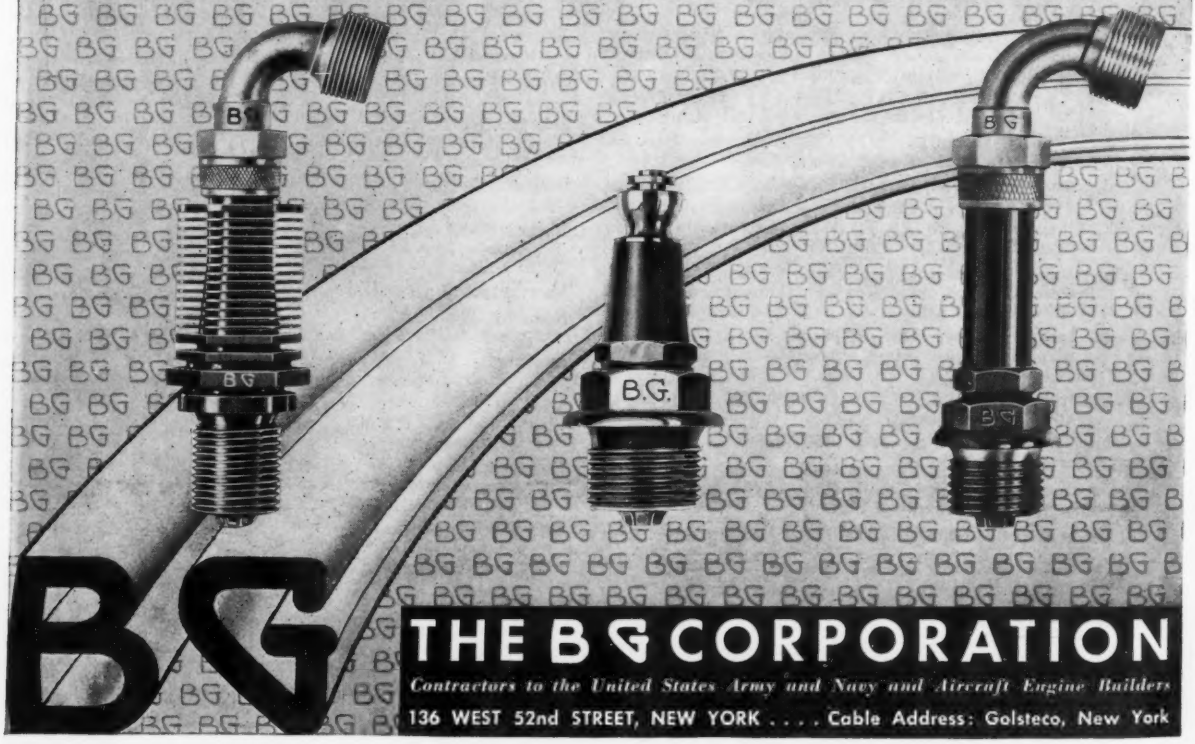

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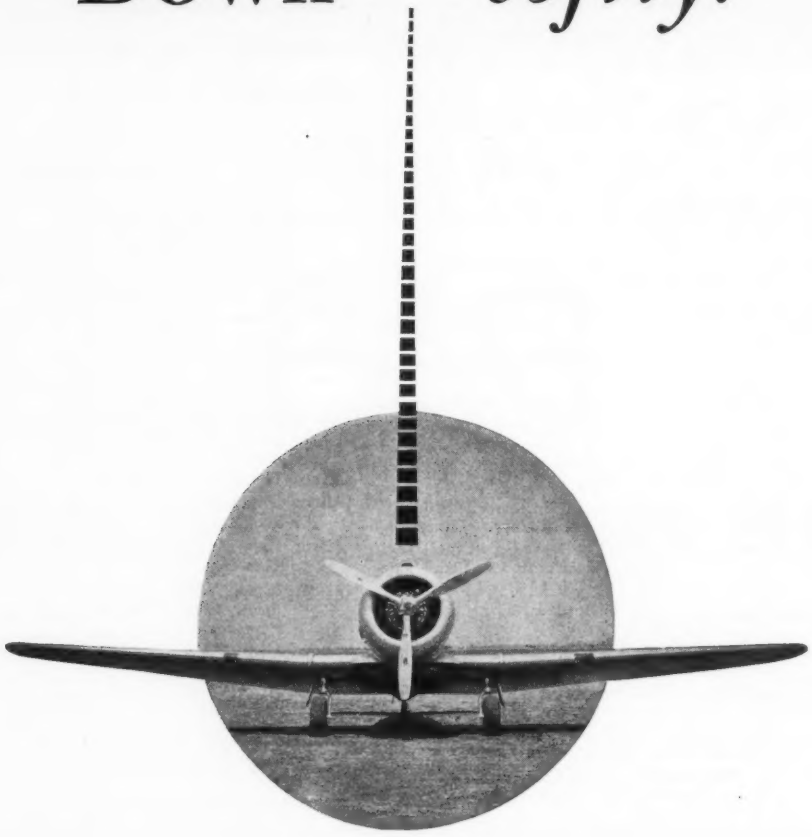

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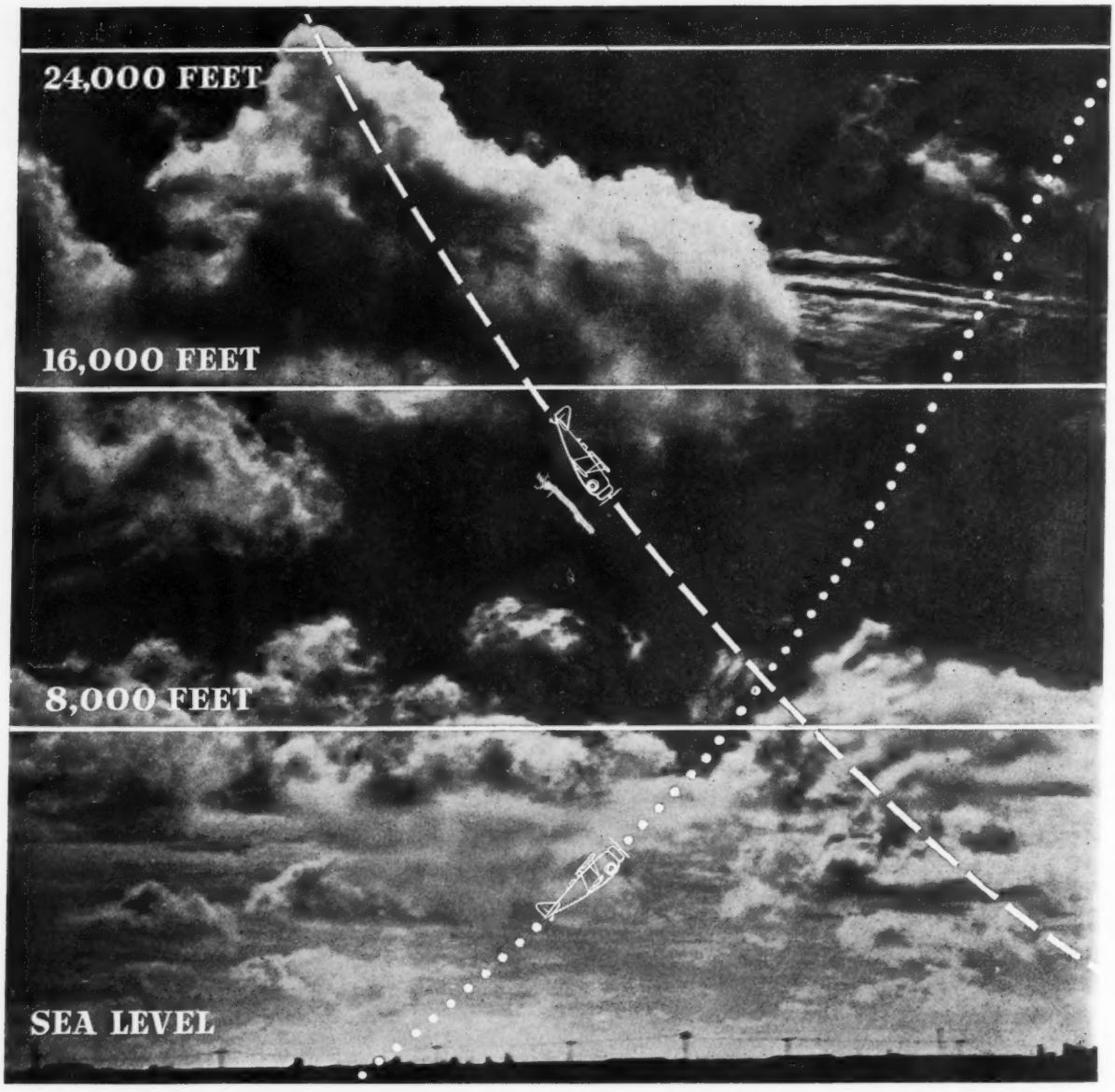

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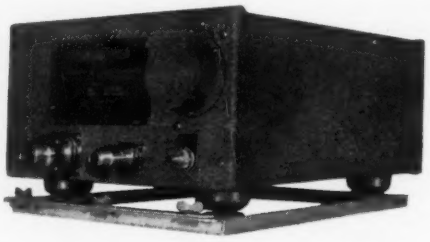

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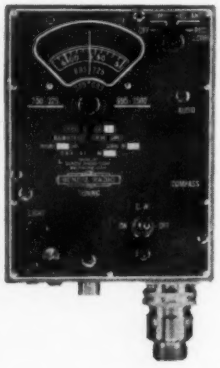

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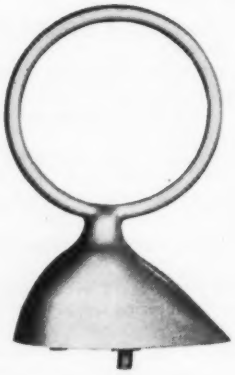

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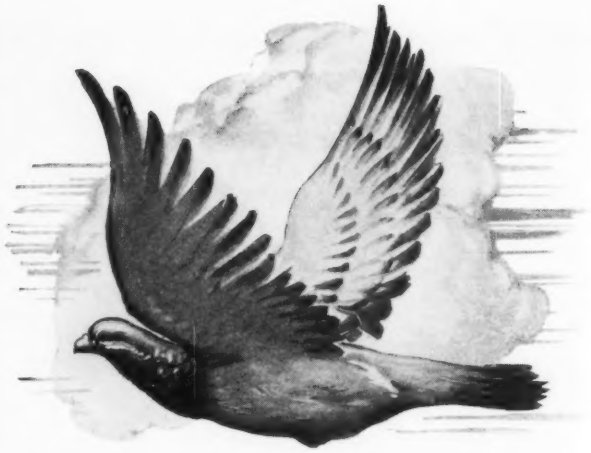

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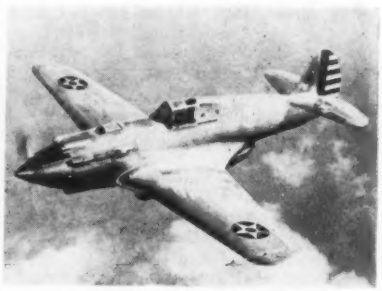

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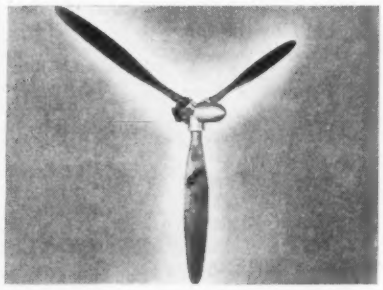

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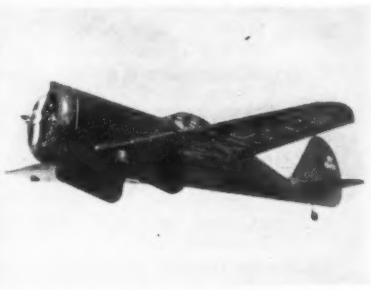

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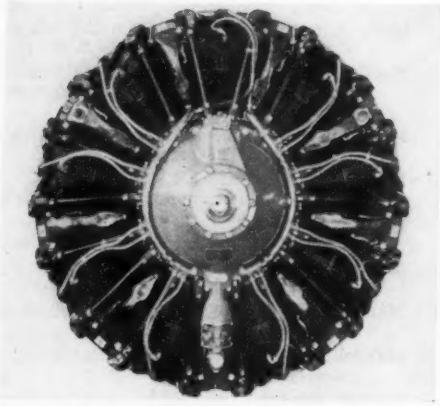
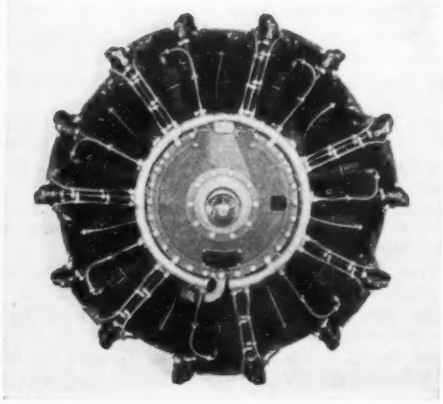


Wright Cyclone 1200 hp. 9-Cylinder, Single-Row, Radial, Air-Cooled Engine.



Wright Cyclone 1600 hp. 14-Cylinder Double-Row, Radial, Air-Cooled Engine.

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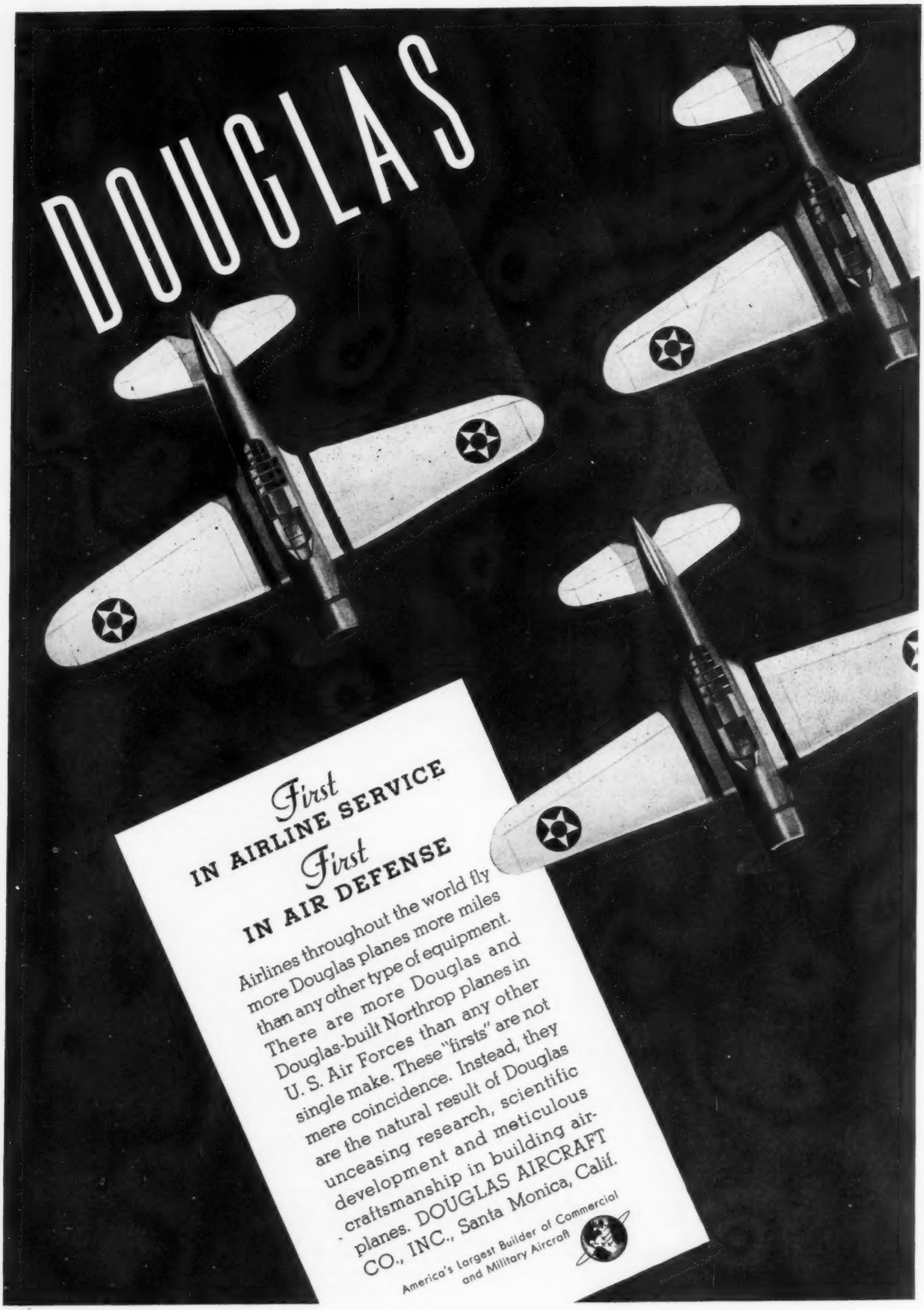
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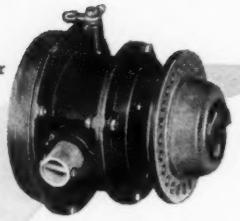

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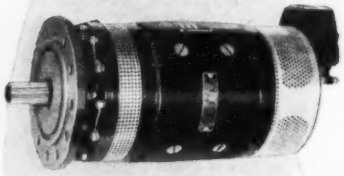

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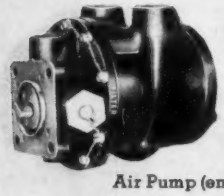

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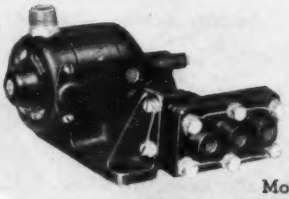

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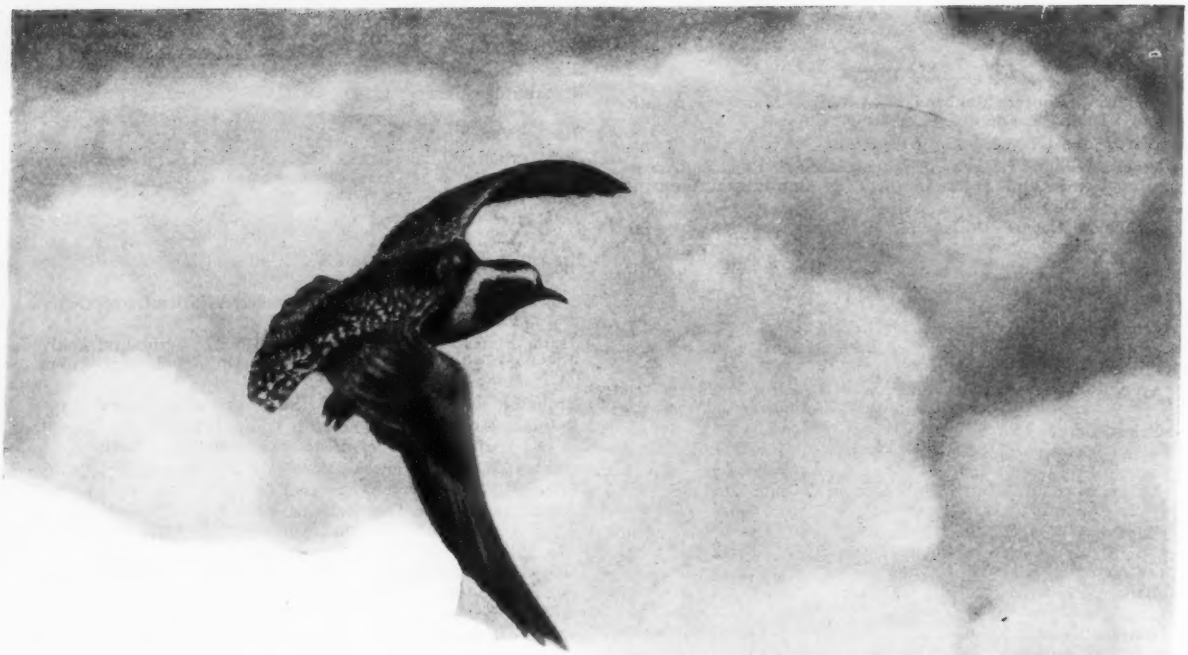

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GOODRICH E.T.* AIRPLANE BRAKES GIVE SMOOTHER SAFER LANDINGS

GREAT PROGRESS has been made in airplane braking since the early use of the "skid" to dig into the ground and bring the plane to a slow, jerky stop. The Low Pressure airplane tire brought new problems and Goodrich engineers set out to find the solution.

After years of study, of development and of testing, both on specially built laboratory equipment and in hundreds of actual flights, Goodrich perfected the Goodrich E. T.* Brake.

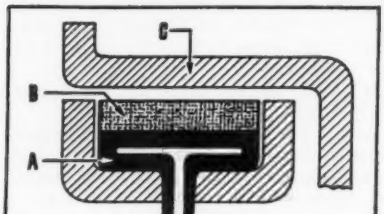
Today, half-ton sport planes and 33-ton giant transports are making quick, safe, smooth landings on the perfect combination of Goodrich E. T.* Brakes and Goodrich Airplane Silvertowns.

The Goodrich E. T.* Airplane Brake is simple and fool-proof. It consists of only three basic elements — the Expander Tube, the brake block, and the retractor spring. Therefore, there is practically nothing to get out of order or require repairs. It automatically compensates for brake lining wear, thus giving much better service at peak efficiency.

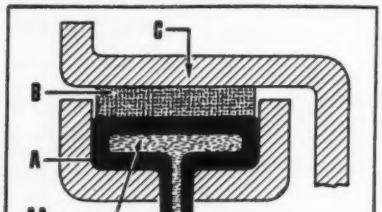
These points of superiority added together mean just this — Goodrich E. T.* Airplane Brakes stop quicker, smoother and safer than any other type of airplane brake.

*Expander Tube

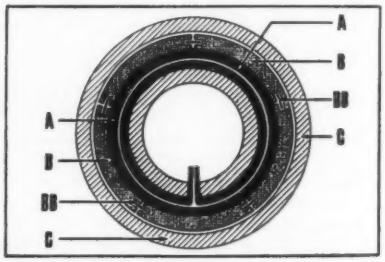
HOW GOODRICH E. T.* AIRPLANE BRAKES WORK



1 Cross-sectional view showing the Goodrich E.T.* Airplane Brake released. The Expander Tube (A) is deflated, the sectional brake block (B) retracted, and the wheel (C) free to turn.



2 The Expander Tube (A) is inflated with braking fluid (AA), forcing the sectional brake block (B) against the brake drum (C), bringing the plane to a swift, smooth, safe stop.



3 The full circle of sectional brake blocks (B) is joined together by metal retractor springs (BB). When the Expander Tube (A) is inflated, these brake blocks press *evenly* against the brake drum (C) all the way around. When the Expander Tube deflates, the springs retract, pulling the brake blocks back from the drum and letting the wheel turn free without drag.

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Smith, Cyrus Rowlett, M.I.Ae.S.; Pres., American Airlines, Inc.

Sopwith, T. O. M., M.I.Ae.S.; F.R.Ae.S.; Chairman, Hawker Siddeley Aircraft Ltd. England. (See B.W.W.)

Southee, Earl Raymond, B.S.; M.I.Ae.S.; Private Flying Specialist, C.A.A.

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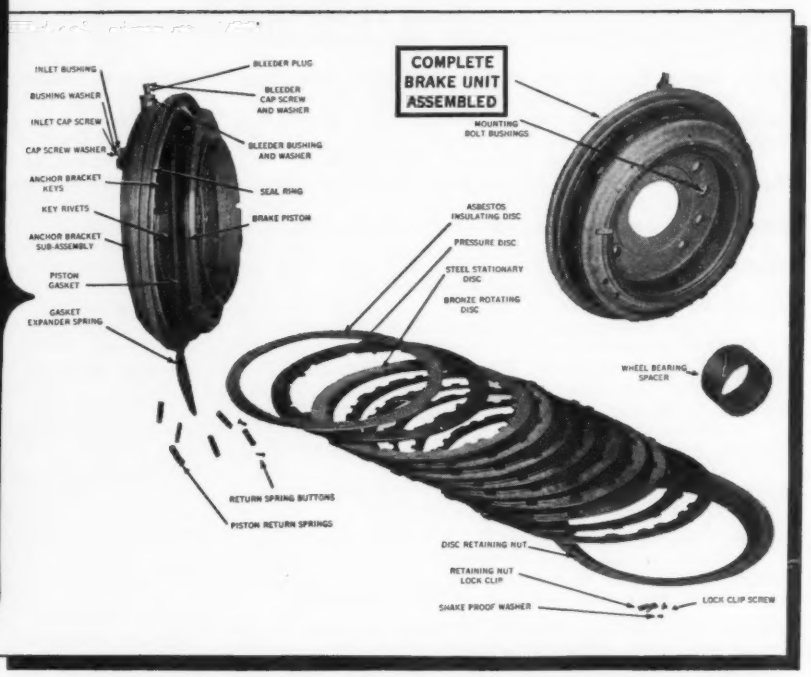
An important message about LANDING GEAR to designers of larger, faster ships



GOODYEAR HYDRAULIC DISC TYPE 15.00-16 AIRPLANE BRAKE —*disassembled.* Greater braking power without increase in brake and wheel diameter can be obtained by increasing number of discs in brake housing.

As ships increase in size and speed the need for greater braking power brings up important considerations in size and weight of wheel assembly, and in housing facilities for landing gear when retracted!

In conventional wheel assemblies where braking power is in direct ratio to brake drum area the only way to step up brake capacity is to employ a larger and heavier drum, with a corresponding increase in wheel and tire size that requires larger housing space.

GOODYEAR AIRPLANE TIRE, TUBE AND WHEEL ASSEMBLY WITH HYDRAULIC DISC BRAKE — tire, tube and wheel shown mounted on axle, ready to slide into position on the brake.

Fortunately, there is a better solution. Brake capacity can now be increased to meet any load and speed requirement with relatively little growth in wheel and tire size by the use of a complete Goodyear wheel assembly—Goodyear magnesium or aluminum alloy wheels, Goodyear hydraulic disc brakes and Goodyear tires, including Airwheels*.

In the Goodyear assembly, braking power depends upon the number of discs in the brake housing. Brake capacity is increased by using more discs to provide larger braking area. There is no appreciable increase in diameter of either brake or wheel, hence the gain in size and weight is held to a minimum.

Because of this definite and easily demonstrable advantage Goodyear wheel equipment is now being specified on many of the largest ships in production today. Engineers also find that using wheels, brakes, and tires designed and built to work together as a balanced unit insures smoother, more dependable performance.

Our engineers will be glad to cooperate with you in incorporating the advantages of this time-proved wheel equipment in your new ships—in both conventional and tricycle gear. Just write Goodyear, Aeronautics Department, Akron, Ohio, or Los Angeles, California.

*Trade-mark of The Goodyear Tire & Rubber Company

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Clauser, Francis, Ph.D.; Engineer, Douglas Aircraft Co.

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Cohan, Sid, Engineer, Brewster Aeronautical Corp.

Cole, Robert A., M.E.; Vibration Project Engineer, Wright Aeronautical Corp.

Colman, Philip Abbey, M.S. in Ae.E.; Aero. Engineer, Aerodynamics Dept., Lockheed Aircraft Corp.

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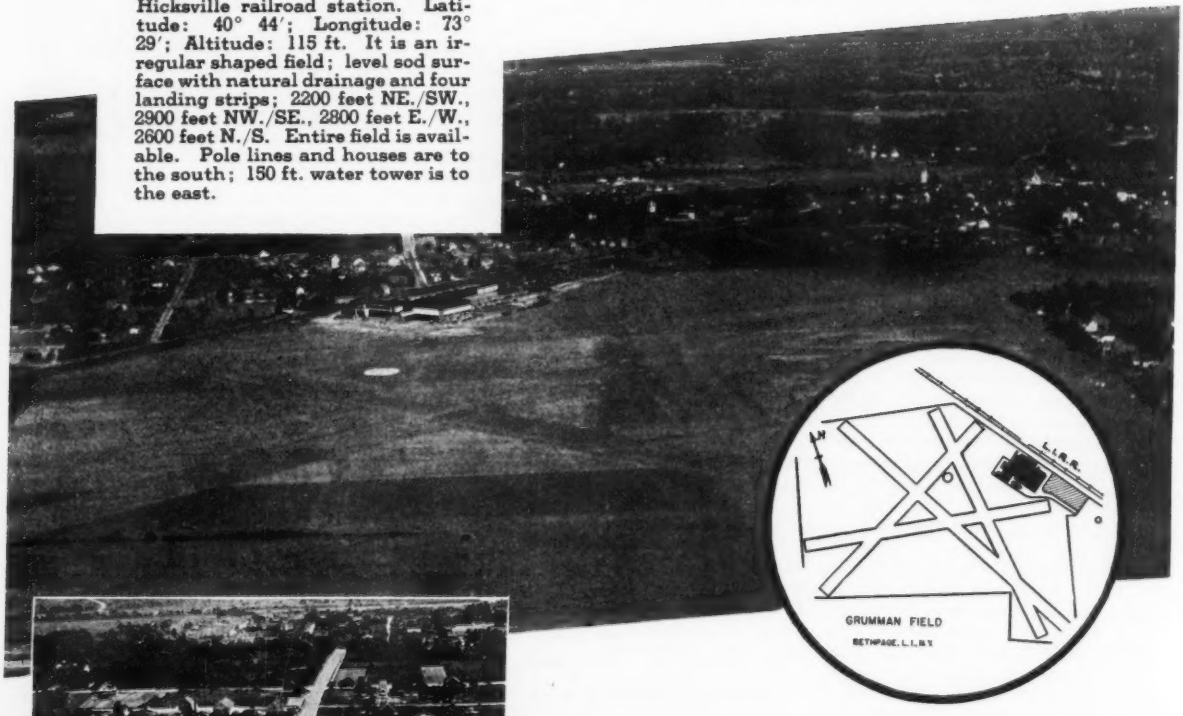

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The Birdmen's Perch

Pilots just aren't the men they used to be when we were young. In those days a flyer'd as soon lie as fly. Wasn't a one wouldn't have taken it as a matter of honor hardly to rest till he got one of our Whopper Diplomas. Now lying's a lost art among modern practitioners. Or is it? If you think you can qualify to compete with the old-timers, send in your most hyperbolous fabrication in re Gulf Aviation Gas to:

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THE EDITOR'S MAILBAG

A novel club seems to have sprung up among our contribs. It's called Stuffing-Answers-to-Allegedly-Hard-Projection-Problems-Down-the-Editor's-Throat, Inc. We got so many to the last one that we're taking a month off to lick our wounds and dream up a jim-dandy of a rip-snorter of a lollapalooza.

In the meantime here are a few of the club members who've scored on us lately: W. J. "too easy" Brown; Johnny "this time I got it without my instructor" Childs; Howard J. "kindergarten stuff" Ide; Robert J. "quit kidding us" Page; Bob "get one hard" Newill; Lyle E. "this may start a feud" Dambruch; Bill Hartley; Harmon "they're getting easier" Van Winkle; Walter "much easier" Thomson; Clarence Thomas; Pvt. Edward A. Kresan; Frank Commisso; P. Morotchic; Walter Dinteman; W. Blake "is somebody's fez red!" Henderson; E. N. Grimwood; E. Dennis; Bill Corbett and Bob "How about something hard?" Dickey; Norman E. Schmidt; and J. B. "the printed matter . . . might have led one to think it was rather difficult" Trenholm.

Laugh while you may, palsies, we're turning on the heat in August.

Or else throwing in the sponge!

CONCENTRATE

Remember when you watched your mother making ice cream back in barefoot days? While the freezer was turning you probably wondered how just a few drops of vanilla could flavor a whole freezerful. The answer, of course, was that the vanilla extract was *concentrated*.

As you probably guessed, this is leading up to our Gulfpride Oil. The point we're making is that, in comparison with other oils, Gulfpride is *concentrated*. Gulf's own Alchlor process—used in addition to conventional methods—digs down deeper into the 100% Pennsylvania—removes still more dirt and sludge. *The result!* There's more lubricating power per drop in Gulfpride. And that means more protection for your airplane motor.

However, for use in making ice cream, we'll still take vanilla.

FANTASTIC FINANCE

Three pilots we know went to a hotel on Friday.

On Sunday afternoon they called for their bill which was $30. They each paid $10 and went upstairs to pack.

In filing the bill, the cashier discovered

that it should have been $25. So he sent a bellboy up with a $5 rebate.

On the way, the bellboy decided the pilots would never know the difference, and he pocketed $2. The remaining $3 he split among the pilots.

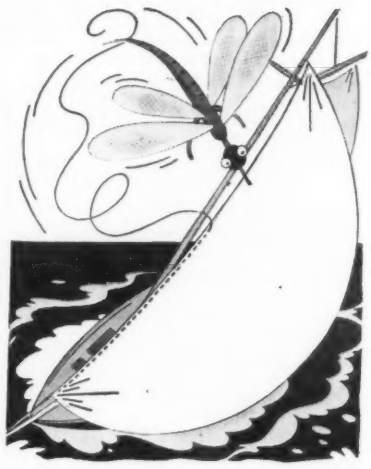
This $1 each, subtracted from the original $10 each had paid, left each out $9.

3 x $9=$27. $27 + the $2 taken by the bellboy=$29.

The pilots originally paid $30, so what happened to the other dollar?

Don't get too mad, boys, if you can't figure this out. We couldn't either. Send your idea of what's wrong to T. W. T. and we'll break the official explanation to you as gently as possible.

THIS MONTH'S WHOPPER



Dear Major:

Norman McEwan's experience with Gulf Aviation Gas and mosquitoes might seem implausible to some. But not to me.

Down East here in Gloucester one of the boys has a pet darning needle (some calls 'em dragon flies) that he rents out to yachtsmen. On ordinary gas it's all the poor beastie can do to finish a light canvas sail for a 10-foot dinghy in an afternoon.

But on one swig of Gulf Aviation Gas that flying seamstress has been known to whip out a balloon spinaker for a Class J sloop in 10 minutes . . . *hemstitching all the way!*

'Struth,

Dapper Dan Shea

Gulf Oil Corporation and Gulf Refining Company . . . makers of

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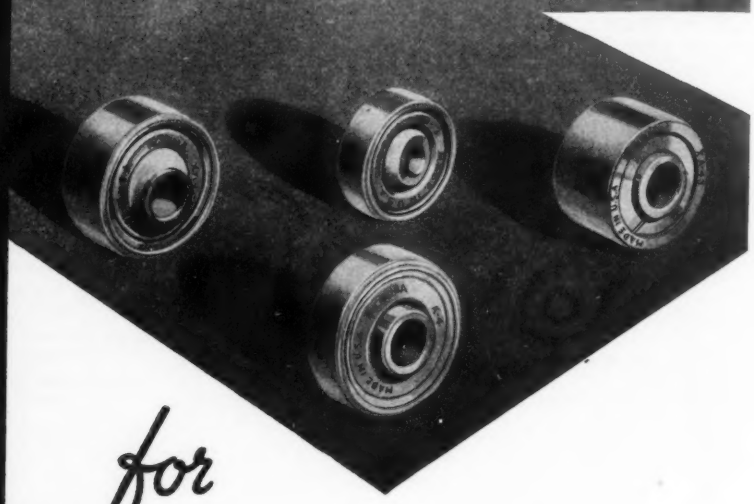

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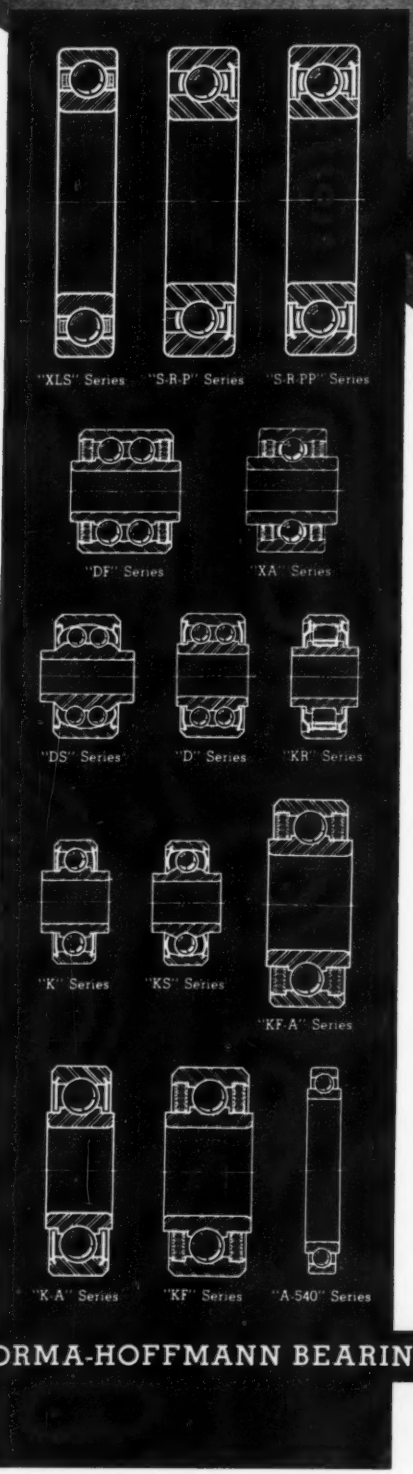

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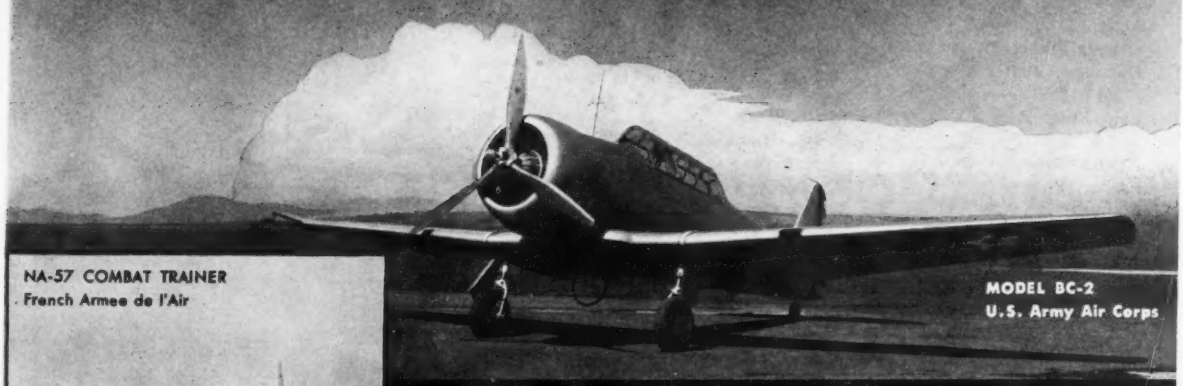

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ABBREVIATIONS

A.—Arts.
A.C.Res —Air Corps Reserve.
Ae., Aero.—Aeronautical, Aeronautics.
A.F.—Associate Fellow.
Asst.—Assistant.
B.—Bachelor.
C.—Civil, Companion.
C.A.A.—Civil Aeronautics Authority.
Chem.—Chemical, Chemistry
Comdr.—Commander.
D., Dr., Dott.—Doctor.
Dept.—Department.
D.I.C.—Diploma, Imperial College, London.
Dipl.—Diploma.
Div.—Division.
E.—Electrical, Engineering.
F.—Fellow.
Hon.—Honorary.
I.Ae.S.—Institute of the Aeronautical Sciences.
Inst.—Institute.
Ing.—Engineering.
Lieut.—Lieutenant.
M.—Master, Mechanical, MEMBER.
Math.—Mathematics.
Mech.—Mechanical.
N.A.C.A.—National Advisory Committee for Aeronautics.
Ph.—Philosophy.
Phys.—Physics.
Pres.—President.
Prof.—Professor.
R.Ae.S.—Royal Aeronautical Society (England).
R.A.F.—Royal Air Force (England).
R.C.A.F.—Royal Canadian Air Force.
Ret.—Retired.
S., Sc.—Science.
Tech.—Technology, Technical.
Univ.—University.
U.S.C.G.—United States Coast Guard.
U.S.N.—United States Navy.
U.S.N.R.—United States Naval Reserve.

REFERENCES

A.M. of S.—American Men of Science.
B.B. of A.—Blue Book of Aviation.
B.W.W.—British Who's Who.
W.W. in A.—Who's Who in America.
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ABBREVIATIONS

(*A list of all abbreviations used in the Biographical section will be found on page 29*)

AF—Associate Fellow (see pp. 5–12)
F—Fellow (see pp. 2–5)
HF—Honorary Fellow (see p. 2)
M—MEMBER (see pp. 13–18)
S—Student Member (see pp. 24–29)
T—Technical Member (see pp. 18–24)
TM—Temporary Honorary Member (see p. 5)

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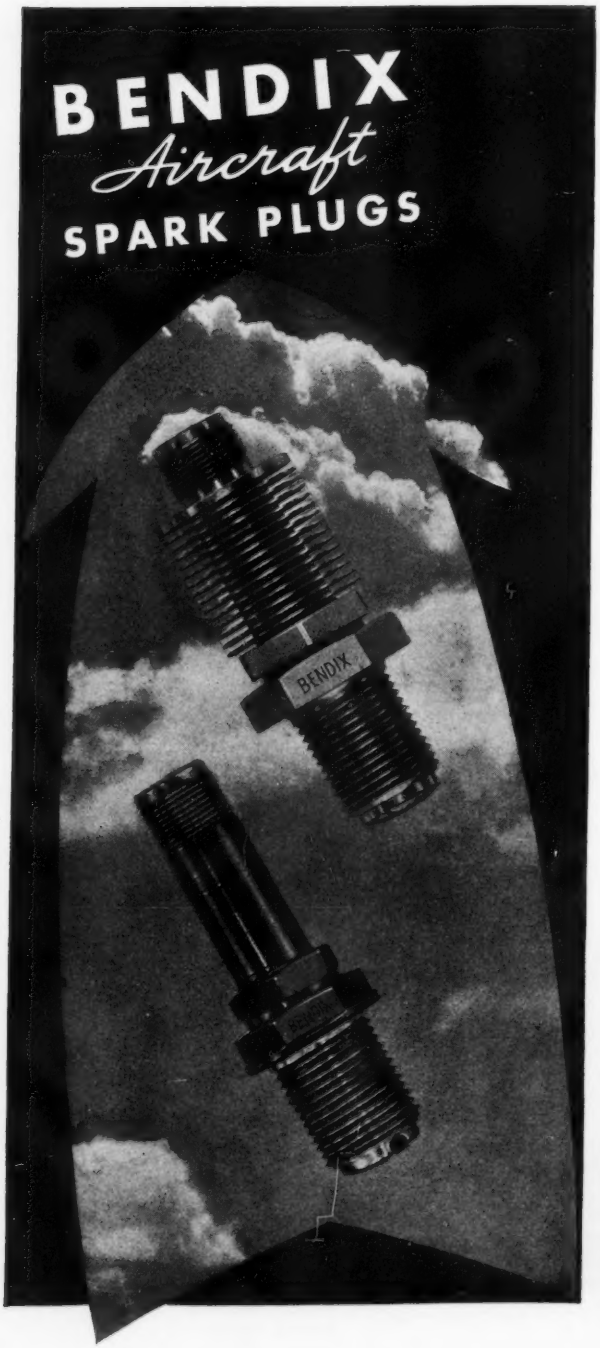

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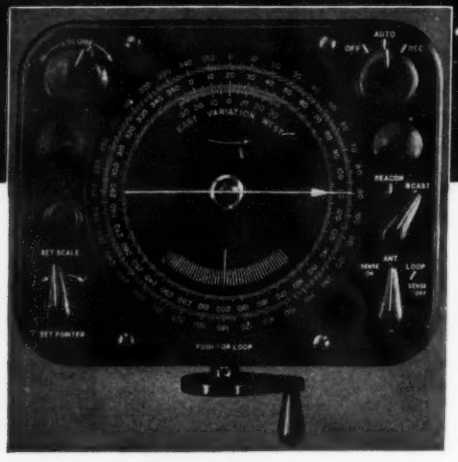

Close-up of the Automatic Direction Finder's Control Unit

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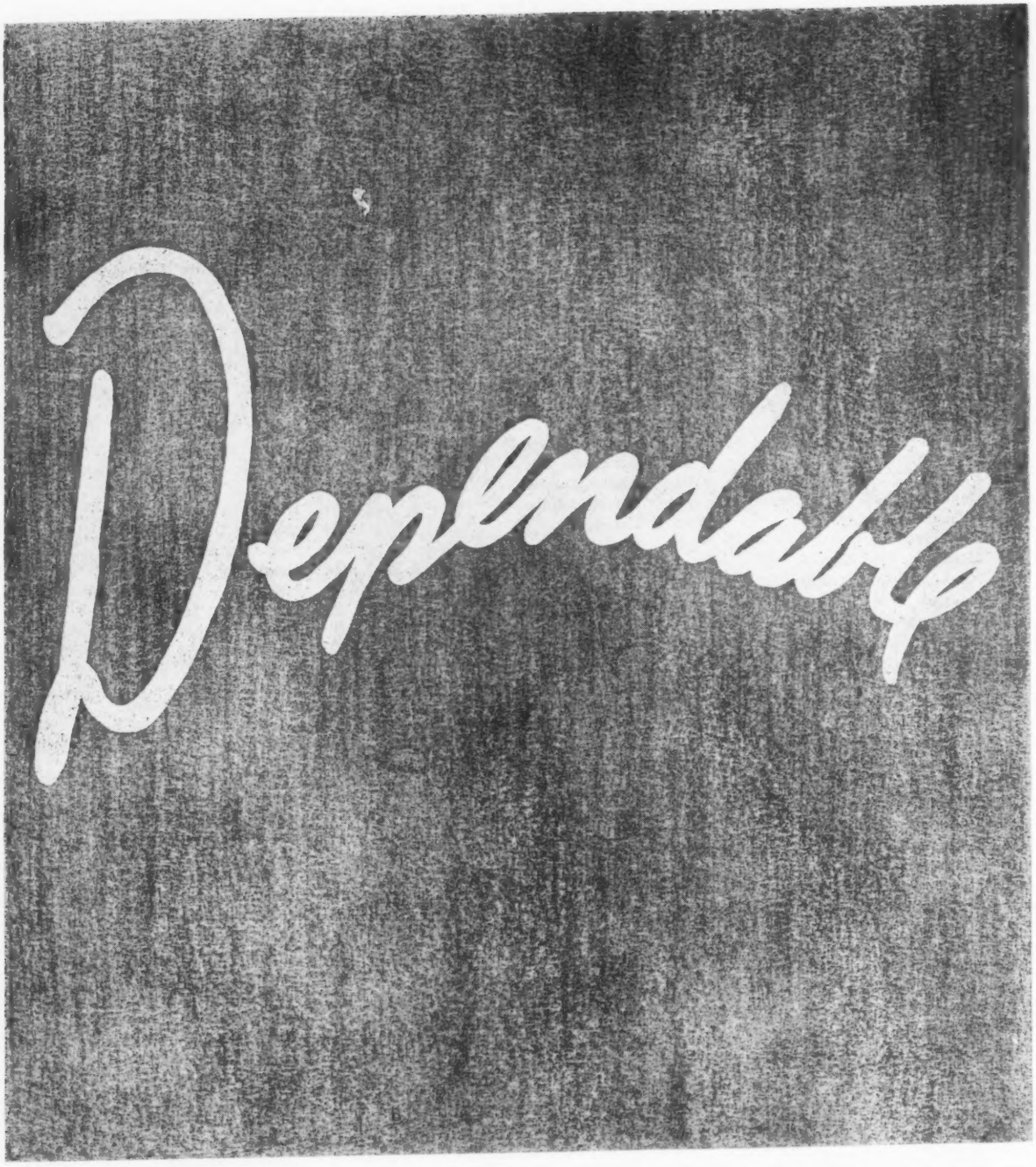

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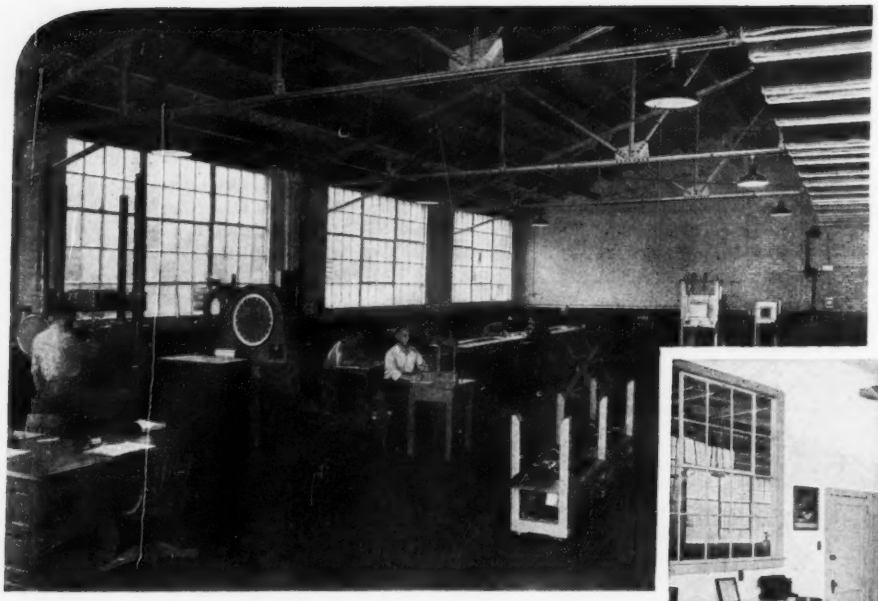
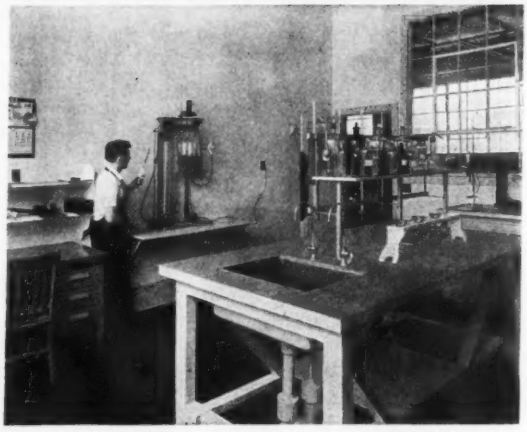


At left, main room in new Summerill Laboratory showing tensile testing apparatus, Rockwell machine, furnaces, and an inspection table for small, special tubing.

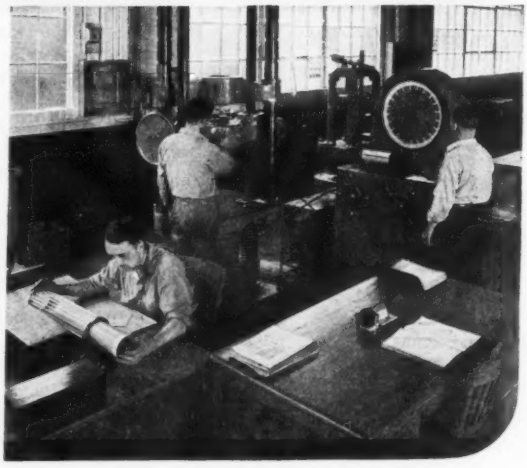
Top view in panel shows the office of the Chief Metallurgist, with photomicrographic equipment and entrance to photographic dark room.

BETTER CONTROL
for manufacturing
SEAMLESS TUBING

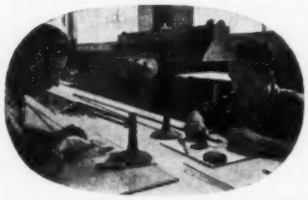


● Chemical and metallurgical control is so essential in guiding production of Summerill Tubing that a new laboratory building has been constructed giving the technical staff the best of modern equipment and ideal working conditions.

● At Summerill, the laboratory exercises complete control over all processing — cold-drawing, annealing, inspection and other factors governing quality. Billets are selected for steel characteristics; cold-reduction is limited to preserve proper grain structure; annealing practice is regulated to produce the best, *i. e.*, the most suitable properties for each requirement.



Center view in panel shows a portion of the Chemical Laboratory which is equipped with the most modern apparatus for chemical control. At right in panel is a close-up of operators at hydraulic tensile machine with test being made using an extensometer. A beam type machine is in background. Oval at left shows inspectors examining the surfaces of special, small tubing under 5-power glass.



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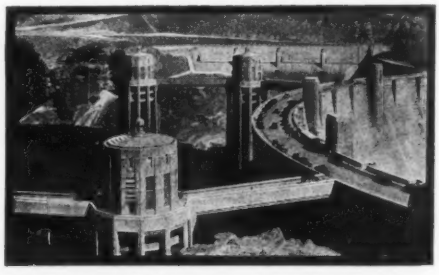

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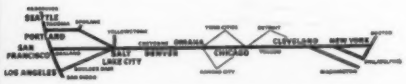

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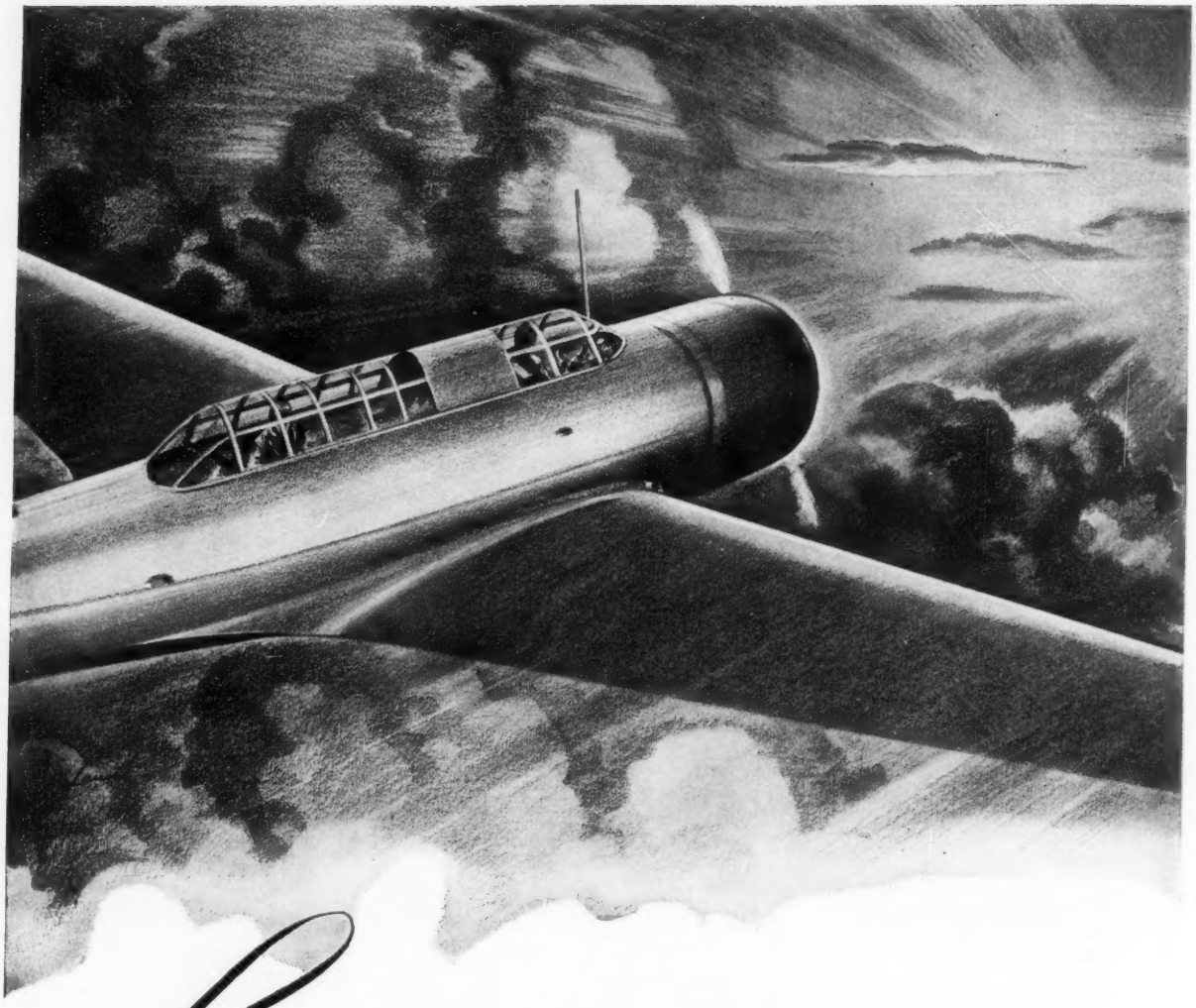
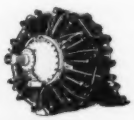


Looking AHEAD

United Aircraft has consolidated its two famous airplane manufacturing units into a single division, Vought-Sikorsky Aircraft, operating in a greatly enlarged plant at Stratford, Connecticut. Together with important additions to its engine and propeller divisions at East Hartford, this provides United Aircraft Corporation with greater facilities than ever before for the design, development, and production of its products, famous wherever man flies.

With America's future supremacy in the air dependent to a great extent on her capacity for producing aviation equipment of superior performance in large quantities, this program of expansion is an important step . . . and one that is typical of United Aircraft Corporation's policy of looking ahead.

UNITED AIRCRAFT CORPORATION
East Hartford, Connecticut



★ PRATT & WHITNEY ENGINES ★ VOUGHT AND SIKORSKY AIRPLANES ★ HAMILTON STANDARD PROPELLERS ★

T Whitaker, John A.
T White, F. Stanley
T White, George C., Jr.
M White, H. J.
AF White, Karl H.
T White, Richard P.
T White, Roland J.
AF White, W. W.
M Whiteley, Major John F.
S Whiting, Arthur A., Jr.
M Whitney, C. V.
S Whitson, Charles
AF Wibault, Michel
T Wichers, Wm. A.
S Wickersham, R. O.
T Wiebe, Albert I.
T Wiegel, G. A., Jr.
T Wiele, Robert F.
S Wier, Harold L.
T Wiese, R. R.
F Wieselsberger, Prof. Dr. C.
S Wiesner, Wayne
S Wilcos, W. W.
T Wild, J. M.
S Wilder, Robert G.
M Wilford, E. Burke
T Wilkes, W. H.
S Wilkie, James S.
T Wilkin, Gerard L.
T Wilkins, Theodore W.
F Wilkinson, Capt. G. S.
AF Willett, Dr. H. C.
M Willey, G. T.
F Willgoos, Andrew V.
M Williams, Alford J.
S Williams, A. N.
S Williams, D. H.
S Williams, G. K.
S Williams, H. B.
S Williams, J. Kenneth
S Williams, L. F., Jr.
S Williams, R. H.
S Williams, Sears
S Williams, W. C.
S Williamson, Donald B.
S Williamson, Lowell
M Willis, A. O.
M Willis, Horace H.
M Willis, J. G.
S Willson, H. M.
S Wilson, Charles J.
T Wilson, Don P.
S Wilson, Elton C.
M Wilson, Eugene E.
AF Wilson, J. A.
S Wilson, Thomas L.
F Wimperis, H. E.
T Winton, S. Victor
S Wirth, Charles A.
AF Wise, Prof. Joseph A.
S Withers, W. B.
M Witherspoon, B. H.
F Witoszynski, Prof. C.
S Wittke, J. N.
T Wodrich, Edmund G.
S Woersching, Thomas B.
S Wolcott, Fred W.
S Wold, Robert
M Wolf, Alfred L.
F Wolff, Dr.ir. E. B.
S Wolff, Leo M.
S Wolfe, Leon
S Wong, L. F.
AF Wong, Lt. Col. Tsoo
T Wood, Amos L., Jr.
M Wood, C. R., Jr.
M Wood, Carlos
F Wood, Donald H.
M Wood, Capt. Eric W.
AF Wood, K. D.
T Wood, Louvan E.
AF Wood, R. McKinnon
AF Woods, Dr. Baldwin M.
AF Woods, R. J.
S Woolard, Henry
S Woolwine, W. E.
M Wooten, Wesley M.
M Work, James
S Worsley, Robert
S Wozniak, Frank B.
S Wuertele, L.
S Wuerz, Oscar W.
S Wunderlin, George J.
M Wright, Burdette S.
S Wright, Fred A.
S Wright, John A.
HF Wright, Orville
F Wright, T. P.
T Wrigley, D. A.
T Wrigley, Walter
M Wronsky, Major Martin
T Wylder, L. Newton
T Yahle, Daniel I.
S Yamamoto, F. M.
S Yarber, R. F.
T Yassin, I. B.
S Yates, William
T Yee, Fred T.
T Yeomans, John H.
S Yopp, A. M.
S Yoshida, G. A.
T Young, B. H.
M Young, Col. Clarence M.
T Young, John P.
S Young, P. H.
M Young, Raymond W.
S Young, Walter G.
S Youngberg, Ralph O.
F Younger, Prof. John E.
S Yu, K. F.
S Yuan, Shao Wen
S Yung, Pei-Lin
F Zahm, Dr. A. F.
S Zahnow, Orlen C.
F Zand, Stephen J.
S Zarkowsky, Wm. M.
S Zdanaitis, Vit
S Zeitlin, Eli A.
M Zelcer, F. William
S Zeliff, B. Sherman
S Zengerle, J. C., Jr.
S Zerbe, Earl M.
T Zimmerman, C. H.
AF Zimmerman, Paul
T Zinberg, Herbert
T Zinn, Rahland
AF Zinsser, A., Jr.
T Zipp, Harold W.
M Zuckerberg, Harry
S Zusi, A. J.

Institute of the Aeronautical Sciences

Membership on September 1, 1939 compared with that on October 1, 1938

	October 1, 1938	September 1, 1939
Honorary Fellows	13	16
Fellows	73	168
Temporary Honorary Members	6	8
Associate Fellows	590	504
MEMBERS	271*	369
Technical Members	428	522
Student Members	897	1,215
Totals	2,278	2,802

* This combines the MEMBERS, Industrial Members, and Pilot Members from the 1938 records.

1939-1940

The United States Aircraft Insurance Group has completed eleven years of service to the Aircraft Industry. Originally consisting of a membership of eight companies, the USAIG membership now totals forty-five companies with combined policyholders' surplus of $619,000,000.

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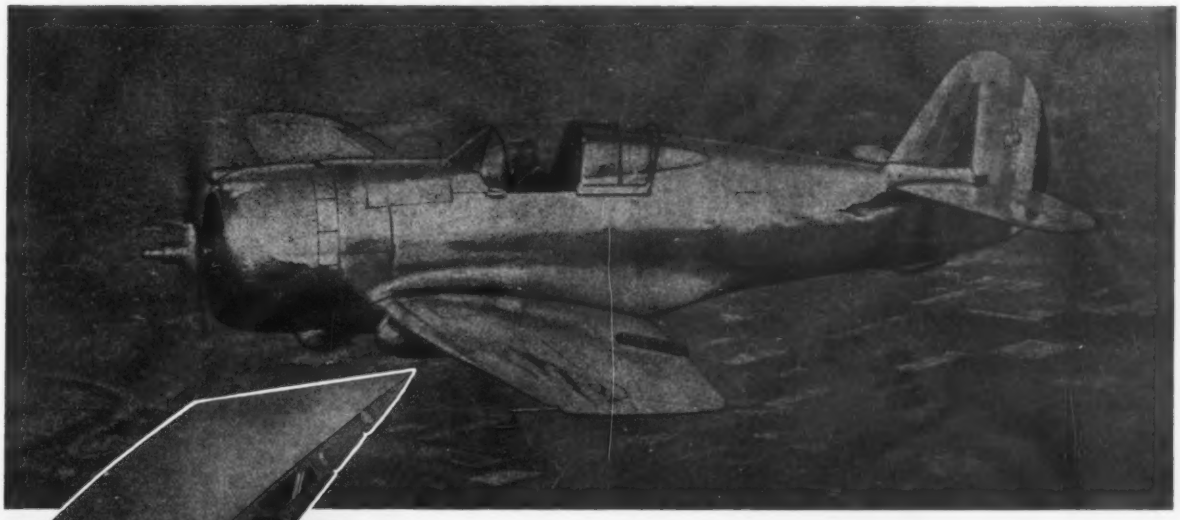
AMERICAN AIRCRAFT *Zooms Ahead*



(Above) **Section of wing for high-speed pursuit ship. Built up from corrugated sheet and tubular members of U·S·S Stainless Steel, all spot-welded together, and sheathed in stainless. Its smooth, rivetless surfaces require no paint, varnish, or lacquer to guard them against time and weather.**

(In panel) **All-stainless framework of elevator. In framework construction like this, stainless contributes precious savings in weight because of its high strength-weight and modulus-weight ratios. Makes possible faster production, because it can be fabricated with modern, high-speed spot-welding equipment.**

... as stainless steel provides the newest forward step to speed, safety, lightness

INDEPENDENT authorities agree that American aviation leads the world in safety and maneuverability. Responsible for this leadership has been this one factor: the aggressive, uninhibited policies of our designers and builders.

It is this policy of ceaseless, unrelenting improvement which, we venture to predict, will *keep* America's aircraft in the lead. As soon as new materials and new methods are proved to be better, less costly, or generally more satisfactory, America will adopt them speedily and wholeheartedly.

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2. **Faster Production Rates,** because stainless can be fabricated safely with modern high-speed spot-welding machines.
3. **Lower Maintenance Costs,** because it requires no paint, varnish, or lacquer to protect the surface against time and weather.
4. **Greater Safety,** because it withstands temperatures up to 1650°F. This property makes stainless invaluable for vital parts wherever hot exhaust gases are handled.

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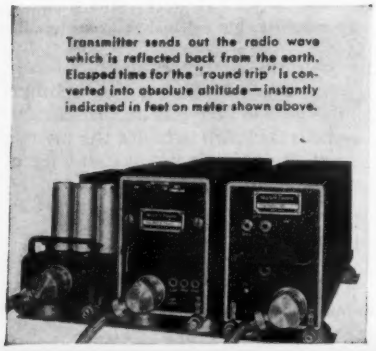

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AIMS

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